

## RESULTS

### EPA REGION 9: PLANTS 1 AND 2

#### Plant Operations and Sampling

On October 30, 2000, January 23, 2001, July 17, 2001, and March 19, 2002, two treatment plants in EPA Region 9 were sampled.

The treatment processes at plant 1 (Figure 1) included ozonation, flocculation, coagulation, sedimentation, and filtration. A secondary disinfectant was not applied until after the filters, so the filters were operated biologically. After the filters, the water was chlorinated with a short, free chlorine contact time, and then ammonia was added to form chloramines. Note, the basins at plant 1 were chlorinated (using sodium hypochlorite) on average twice per week for approximately four hours. This chlorine was applied to the effluent of the ozone contactors to help control algae and other growths in the basins.

Plant 1 was sampled at the following locations:

- (1) raw water before the ozone contactor
- (2) the ozone (O<sub>3</sub>) contactor effluent
- (3) the filter influent
- (4) the filter effluent
- (5) the clearwell effluent
- (6) the finished water

The treatment processes at plant 2 (Figure 2) included coagulation and filtration. Chlorine was applied to the raw, settled, and filtered waters. Ammonia was added to the finished water to form chloramines.

Plant 2 was sampled at the following locations:

- (1) filter influent (settled water) or filter effluent
- (2) the effluent of the treated water tank
- (3) the finished water

In addition, finished water was collected from both plants, and simulated distribution system (SDS) testing conducted for average and maximum detention times for that time of the year (Table 1). Furthermore, the distribution system was sampled at two locations, one representing an average detention time and the other representing a maximum detention time. (Raw water was not sampled at plant 2, as it was the same as was used at plant 1.)

**Table 1. SDS holding times (hr) at the EPA Region 9 treatment plants**

Sample	10/30/00	1/23/01	7/17/01	3/19/02
Plant 1 average detention time	18	23	6	65
Plant 1 maximum detention time	NS <sup>a</sup>	48	28	70
Plant 2 average detention time	18	22	4	5
Plant 2 maximum detention time	NS	38	5	10

<sup>a</sup>NS = Not sampled

Figure 1

## Plant 1 Schematic

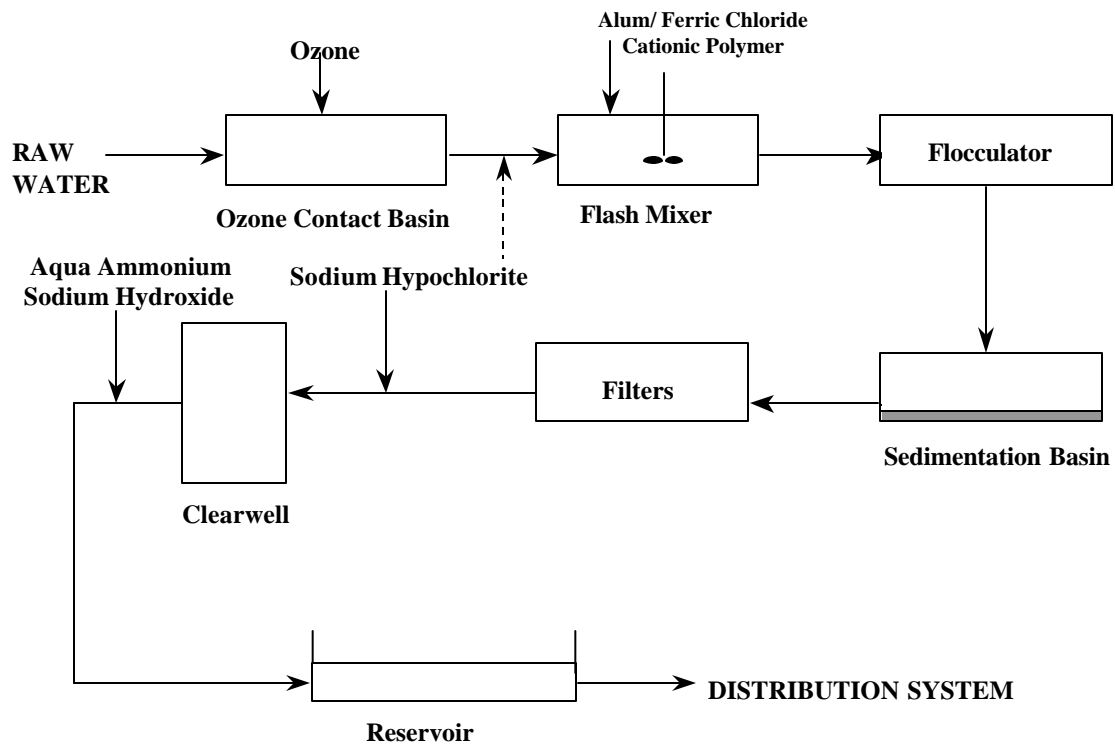
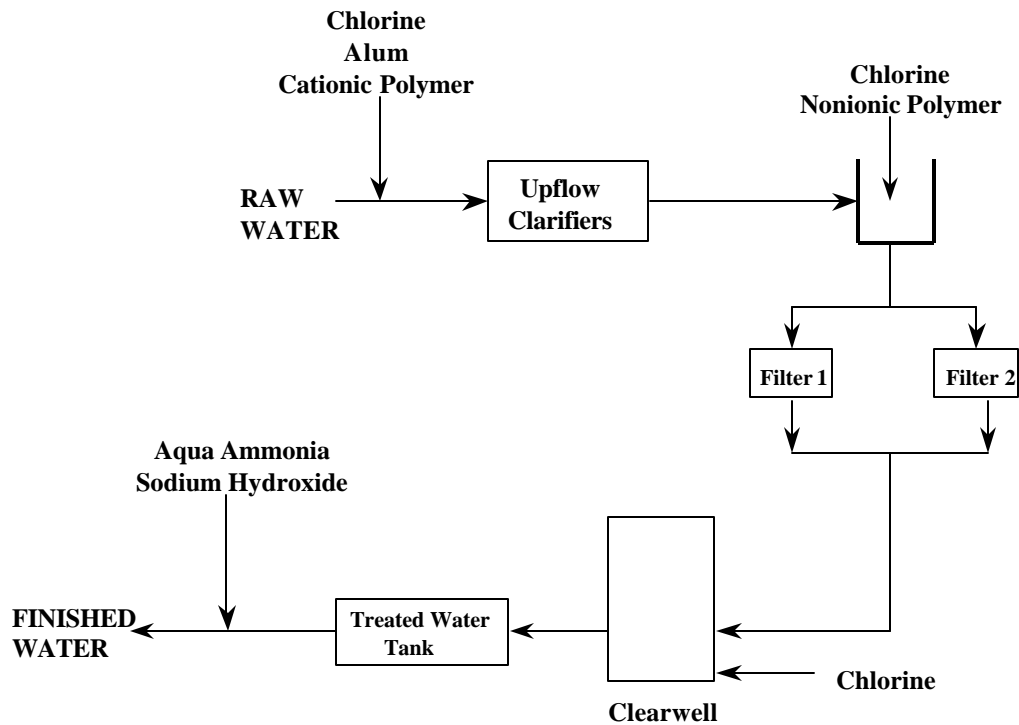


Figure 2

## Plant 2 Schematic



On the day of sampling, information was collected on the operations at each plant (Tables 2-3).

**Table 2. Operational information at plant 1**

Parameter	10/30/00	1/23/01	7/17/01	3/19/02
Plant flow (mgd)	11.0	16.2	22.0	15.8
Ozone dose (mg/L)	1.84	2.53	2.43	2.33
HRT <sup>a</sup> in ozone contactor (min)	4.9	9.5	6	9.8
CT achieved from ozonation (mg/L-min)	1.67	1.24	0.20	3.6
<i>Giardia</i> inactivation achieved from ozonation (logs)	0.75	2.82	1.31	NA <sup>c</sup>
Coagulant <sup>b</sup> dose (mg/L)	14	13	18	16
Filter loading rate (gpm/sq ft)	2.8	3.4	4.7	4.8
Filter EBCT <sup>d</sup> (min)	6.7	7.7	5.5	9
Chlorine dose at ozone contactor effluent (mg/L)	0	0	0	0
Chlorine dose at filter effluent (mg/L)	2.93	4.65	2.15	3.6
Ammonia dose at clearwell effluent (mg/L as N)	0.56	0.72	0.48	0.55

<sup>a</sup>Hydraulic retention time in cells 1 and 2 only

<sup>b</sup>Ferric chloride (FeCl<sub>3</sub>)

<sup>c</sup>NA = Not available

<sup>d</sup>Empty bed contact time through both media layers

**Table 3. Operational information at plant 2**

Parameter	10/30/00	1/23/01	7/17/01	3/19/02
Plant flow (mgd)	6.8	5.6	7.7	4.4
Coagulant <sup>a</sup> dose (mg/L)	20	19	25	12
Chlorine dose at plant influent (mg/L)	1.11	1.3	1.5	1.2
Chlorine dose at filter influent (mg/L)	0.65	0.60	0.8	0.75
Chlorine dose at filter effluent (mg/L)	1.93	2.31	1.95	3.7
Ammonia dose at effluent of treated water tank (mg/L as N)	0.46	0.44	0.5	0.62

<sup>a</sup>Alum [Al<sub>2</sub>(SO<sub>4</sub>)<sub>3</sub> 14H<sub>2</sub>O] on 10/30/00 and 1/23/01, ferric chloride (FeCl<sub>3</sub>) on 7/17/01 and 3/19/02

## Water Quality

On the day of sampling, information was also collected on the water quality at each plant (Tables 4-5).

**Table 4. Water quality information at plant 1**

Location	pH				Temperature (°C)				Disinfectant Residual <sup>a</sup> (mg/L)			
	10/30/00	1/23/01	7/17/01	3/19/02	10/30/00	1/23/01	7/17/01	3/19/02	10/30/00	1/23/01	7/17/01	3/19/02
Raw	8.16	8.3	7.7	9.07	17.3	10.6	20.7	13.6	---	---	---	---
O <sub>3</sub> eff.	8.13	7.89	7.4	7.14	17	10.4	22.3	13.4	<b>0.34</b>	<b>0.26</b>	<b>0.20</b>	<b>0.37</b>
Filt. inf.	7.73	7.20	6.8	6.78	17.3	10.9	21.5	13.8	---	---	---	---
Filt. eff.	7.84	6.90	6.7	6.82	17.1	10.6	21.0	13.9	---	---	---	---
Clear. eff.	7.59	9.0	6.7	6.73	17	10.5	21.4	13.7	2.26	<i>3.61</i>	<i>2.05</i>	<i>2.64</i>
Fin. water	8.20	8.63	8.7	8.22	16	9.7	20.7	13.2	1.81	3.65	1.86	2.81
DS <sup>b</sup> /ave.	8.1	8.74	8.2	8.54	17.1	11.9	22.3	14.7	1.61	1.62	1.81	>2.20
DS/max	8.35	8.65	8.3	8.61	17.9	11.8	21.8	14.4	1.14	0.26	1.78	>2.20
SDS/ave.	8.19	8.09	8.6	8.43	15.6	12.4	21.3	14.2	1.67	1.59	1.86	2.11
SDS/max	NS	8.57	8.2	8.34	NS	10.2	20.8	14.9	NS	1.21	1.80	2.08

<sup>a</sup>Ozone residuals (**values shown in bold**) in effluent of cell 2 of ozone contactor; chlorine residuals (values shown in italics) at clearwell effluent; chloramine residuals at other locations.

<sup>b</sup>DS = Distribution system

**Table 5. Water quality information at plant 2**

Location	pH				Temperature (°C)				Disinfectant Residual <sup>a</sup> (mg/L)			
	10/30/00	1/23/01	7/17/01	3/19/02	10/30/00	1/23/01	7/17/01	3/19/02	10/30/00	1/23/01	7/17/01	3/19/02
Filt. eff. <sup>b</sup>	7.5	7.4	6.7	7.35	17.8	10.7	21.5	13.0	<i>0.72</i>	<i>0.33</i>	<i>0.22</i>	<i>0.26</i>
Treat. tank <sup>c</sup>	7.5	7.3	6.6	7.21	16.4	11.5	21.8	13.2	<i>1.69</i>	<i>1.83</i>	<i>1.91</i>	<i>2.71</i>
Fin. water	7.88	8.3	8.6	8.74	16.3	11.6	21.7	13.4	1.85	1.88	1.84	2.43
DS/ave.	8.23	8.95	8.5	8.98	14.6	10.9	21.4	13.5	1.38	1.35	2.00	1.83
DS/max	8.35	8.69	8.5	8.72	19.6	12.4	21.8	14.0	0.96	0.97	1.78	1.92
SDS/ave.	8.16	8.51	8.14	8.56	17.6	11.4	21.2	14.3	1.55	1.46	1.93	2.13
SDS/max	NS	8.51	8.10	8.67	NS	10.1	20.9	16.1	NS	1.50	2.05	2.20

<sup>a</sup>Chlorine residuals (values shown in italics) at filter effluent and at effluent of treated water tank; chloramine residuals at other locations.

<sup>b</sup>Sampled settled water (filter influent) rather than filter effluent on 10/30/00

<sup>c</sup>Effluent of treated water tank

Other data collected included total organic carbon (TOC) and ultraviolet (UV) absorbance (Table 6). The TOC ranged from 3.0 to 4.5 mg/L and the UV was 0.076 to 0.136 cm<sup>-1</sup>. Typically, ozonation had little effect on TOC. In July 2001, ozonation resulted in a slight increase in the value of the TOC. This phenomenon is due to the conversion of “recalcitrant” TOC by ozone to a form that can be more readily measured by a TOC analyzer. On the other hand, a significant portion of the UV absorbance was reduced by ozone. At plant 1, coagulation removed 27-47 % of the TOC and biofiltration removed another 14-21 %. In addition, coagulation reduced the UV by 38-63 %. The overall (cumulative) removal of TOC at plant 1 was 37-53 % and the UV reduction was 70-81 %. At plant 2, 8-47 % of the TOC was removed and UV reduced by 51-80 % by the coagulation/filtration process.

**Table 6. TOC and UV removal at the EPA Region 9 treatment plants**

Location	TOC (mg/L)	UV (cm <sup>-1</sup> )	SUVA <sup>a</sup> (L/mg-m)	Removal/Unit (%)		Removal/Cumulative (%)	
				TOC	UV	TOC	UV
10/30/2000							
Plant 1 Raw	3.1	0.076	2.4	---	---	---	---
Plant 1 O3 Eff.	3.1	0.039	1.3	1.3%	49%	1.3%	49%
Plant 1 Filter Inf.	2.3	0.024	1.1	27%	38%	27%	68%
Plant 1 Filter Eff.	2.0	0.023	1.2	14%	4.2%	37%	70%
Plant 2 Filt. Eff.	2.9	0.037	1.3	7.7%	51%	7.7%	51%
1/23/2001							
Plant 1 Raw	4.48	0.136	3.0	---	---	---	---
Plant 1 O3 Eff.	4.34	0.070	1.6	3.1%	49%	3.1%	49%
Plant 1 Filter Inf.	3.11	0.031	1.0	28%	56%	31%	77%
Plant 1 Filter Eff.	2.47	0.031	1.3	21%	0%	45%	77%
Plant 2 Filt. Eff.	3.00	0.055	1.8	33%	60%	33%	60%
7/17/2001							
Plant 1 Raw	2.99	0.093	3.1	---	---	---	---
Plant 1 O3 Eff.	3.11	0.048	1.5	-4.0%	48%	-4.0%	48%
Plant 1 Filter Inf.	1.64	0.018	1.1	47%	63%	45%	81%
Plant 1 Filter Eff.	1.4	0.018	1.3	15%	0%	53%	81%
Plant 2 Filt. Eff.	1.57	0.019	1.2	47%	80%	47%	80%
3/19/2002							
Plant 1 Raw	4.5	0.132	2.9	---	---	---	---
Plant 1 O3 Eff.	4.4	0.069	1.6	2.2%	48%	2.2%	48%
Plant 1 Filter Inf.	2.69	0.030	1.1	39%	57%	40%	77%
Plant 1 Filter Eff.	2.2	0.029	1.3	18%	3.3%	51%	78%
Plant 2 Filt. Eff.	3.02	0.060	2.0	33%	55%	33%	55%

<sup>a</sup>SUVA = Specific ultraviolet absorbance = 100\*UV/DOC,  
where DOC = dissolved organic carbon, which typically = 90-95% TOC  
(used TOC values in calculating SUVA)

Table 7 shows the values of miscellaneous other water quality parameters in the EPA Region 9 treatment plants' raw source water. Bromide ranged from 0.12 to 0.40 mg/L. At both plant 1 and plant 2, they treated surface water impacted by saltwater intrusion.

**Table 7. Miscellaneous water quality parameters in plant 1 and 2's raw water**

Date	Bromide (mg/L)	Alkalinity (mg/L)	Ammonia (mg/L as N)
10/30/2000	0.16	106	ND <sup>a</sup>
01/23/2001	0.40	66	0.04
07/17/2001	0.14	72	0.04
03/19/2002	0.12	82	ND

<sup>a</sup>ND = Not detected

The source water was moderate in alkalinity. The raw-water pH varied from 7.7 to 9.1 (Table 4). The source water can have significant variability in these inorganic parameters.

## DBPs

*Oxyhalides.* Ozonation resulted in the formation of <3 to 26 µg/L of bromate (Table 8). Bromate formation was highest in January 2001 when the bromide concentration in the raw water was highest (Table 7).

**Table 8. Oxyhalide formation at the EPA Region 9 treatment plants**

Location	Bromate (µg/L)	Chlorate (µg/L)	Bromate/Bromide (µmol/µmol)
10/30/2000			
Plant 1 O3 eff.	5.7	10	2.2%
Plant 1 clear. eff.	5.2	157	
1/23/2001			
Plant 1 O3 eff.	26	5.9	4.0%
Plant 1 clear. eff.	22	121	
Plant 2 fin. water	ND	114	
7/17/2001			
Plant 1 O3 eff.	4.9	9.8	2.2%
Plant 1 clear. eff.	5.5	133	
Plant 2 fin. water	ND	93	
3/19/2002			
Plant 1 O3 eff.	ND <sup>a</sup> (2)	10	1.0%
Plant 1 clear. eff.	4	80	2.1%
Plant 2 fin. water	ND (1)	127	

<sup>a</sup>ND = Not detected

(bromate minimum reporting level [MRL] = 3 µg/L;  
value in parenthesis is < MRL)

The conversion of bromide to bromate was 1-4 % (on a molar basis), which is a typical conversion rate for an ozone plant operating for *Giardia* inactivation (Douville and Amy, 2000). In addition, sodium hypochlorite can be contaminated with low or sub-µg/L levels of bromate (Delcomyn et al., 2000). In March 2002, there was an increase in the concentration of bromate in the treated water at plant 1 after secondary disinfection (4 versus <3 µg/L). Bromate was not detected (minimum reporting level of 3 µg/L) at plant 2. However, some chlorate was

introduced into the finished waters at both plants from secondary disinfection (Table 8) (chlorate is a by-product formed during the decomposition of the hypochlorite stock solution [Bolyard et al. [1992]).

*Biodegradable Organic Matter.* Ozone can convert natural organic matter in water to carboxylic acids (Kuo et al., 1996) and other assimilable organic carbon (AOC) (van der Kooij et al., 1982). Table 9 shows the carboxylic acid and AOC data for plant 1. Because AOC data are expressed in units of micrograms of carbon per liter ( $\mu\text{g C/L}$ ), the carboxylic acid data were converted to the same units. A portion of the molecular weight (MW) of each carboxylic acid is due to carbon atoms (i.e., 27-49 %) and the remainder is due to oxygen and hydrogen atoms. The sums of the five carboxylic acids (on a  $\mu\text{g C/L}$  basis) were compared to the AOC data. On a median basis for each sample date, 19 to 30 % of the AOC was accounted for by the carboxylic acids.

Figures 3 and 4 show the AOC and the carboxylic acid results, respectively, for the July 2001 sample date. Ozonation resulted in a significant increase in AOC and the concentration of the carboxylic acids, especially oxalate. (Note, one of the bacterial strains used in the AOC method [i.e., *Spirillum NOX*] is used to estimate oxalate-carbon equivalents of the AOC [van der Kooij and Hijnen, 1984].) The carboxylic acids and AOC were both significantly reduced in concentration in the downstream treatment processes (coagulation/sedimentation) prior to biological filtration. Because chlorine was not applied until after the filters, there may have been biological activity in the basins that degraded the AOC. Also, some of the AOC may have been removed by the coagulation process (Volk and LeChevallier, 2002) along with the TOC (Table 6).

Figures 5 and 6 show the formation and removal of AOC and oxalate, respectively, for all of the sample dates. AOC increased from 16-83  $\mu\text{g C/L}$  in the raw water to 504-707  $\mu\text{g C/L}$  in the ozonated water. AOC decreased to 148-333  $\mu\text{g C/L}$  in the settled water and to 131-224  $\mu\text{g C/L}$  in the filtered water. Oxalate increased from 14-18  $\mu\text{g/L}$  in the raw water to 314-409  $\mu\text{g/L}$  in the ozonated water. Oxalate decreased to 56-223  $\mu\text{g/L}$  in the settled water and to 9-33  $\mu\text{g/L}$  in the filtered water. The formation and removal of carboxylic acids—in particular that of oxalate—and AOC tended to follow the same trends through the different treatment processes.

*Halogenated Organic and Other Non-halogenated Organic DBPs.* Tables 10 and 11 (10/30/00), Tables 13 and 14 (1/23/01), Tables 16 and 17 (7/17/01), and Tables 20 and 21 (3/19/02) show results for the halogenated organic DBPs that were analyzed by MWDSC.

**Table 9. Formation and removal of carboxylic acids and AOC at plant 1**

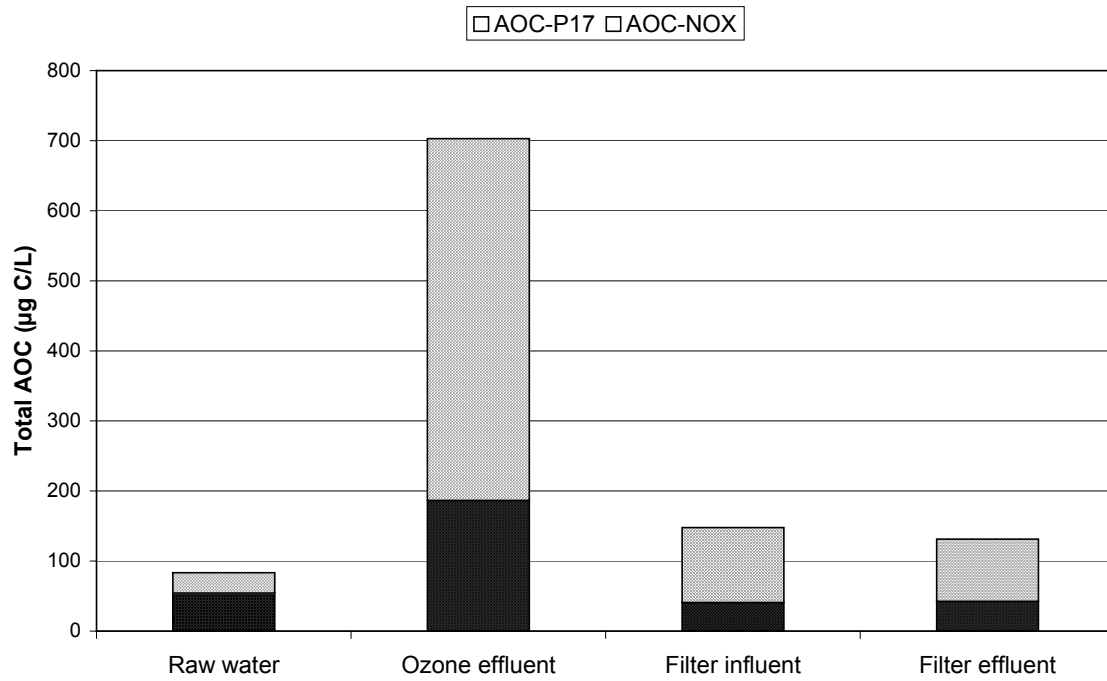
Location	Concentration <sup>a</sup> (µg/L)					Concentration (µg C/L)										Sum/ AOC
	Acetate	Propionate	Formate	Pyruvate	Oxalate	Acetate	Propionate	Formate	Pyruvate	Oxalate	Sum	AOC-P17	AOC-NOX	AOC		
10/30/2000																
Raw water	ND	ND	ND	ND	17	ND	ND	ND	ND	4.6	4.6	N/A <sup>b</sup>	N/A			
Ozone effluent	ND	ND	ND	ND	314	ND	ND	ND	ND	86	86	168	336	504	17%	
Filter influent	ND	ND	32	19	70	ND	ND	8.6	7.8	19	36	N/A	N/A			
Filter effluent	ND	ND	25	25	33	ND	ND	6.6	10	9.0	26	72	101	173	21%	
													median		19%	
1/23/2001																
Raw water	N/A	N/A	N/A	N/A	N/A							13	3.4	16		
Ozone effluent	N/A	N/A	N/A	N/A	N/A							191	386	578		
Filter influent	N/A	N/A	N/A	N/A	N/A							54	279	333		
Filter effluent	N/A	N/A	N/A	N/A	N/A							50	91	141		
7/17/2001																
Raw water	13	ND	15	13	14	5.3	ND	3.9	5.5	3.9	19	54	29	83	22%	
Ozone effluent	80	8.8	223	50	378	32	4.4	60	21	103	220	186	516	703	31%	
Filter influent	16	5.5	43	19	56	6.4	2.7	11	7.9	15	44	41	107	148	30%	
Filter effluent	45	ND	43	14	22	18	ND	12	5.7	5.9	41	43	89	131	33%	
													median		30%	
3/19/2002																
Raw water	11	ND	12	7.1	18	4.3	ND	3.2	2.9	5.0	15	48	4.7	53	29%	
Ozone effluent	77	ND	206	31	409	31	ND	55	13	112	211	266	441	707	30%	
Filter influent	40	ND	125	23	223	16	ND	33	9.5	61	120	38	205	243	49%	
Filter effluent	ND	ND	ND	4.0	8.7	ND	ND	ND	1.7	2.4	4.0	51	173	224	2%	
													median		29%	
Formula	CH3COO <sup>-</sup>	CH3CH2COO <sup>-</sup>	HCOO <sup>-</sup>	CH3COCOO <sup>-</sup>	C2O4 <sup>2-</sup>											
MW (gm/mole)	59	73	45	87	88											
C portion (gm/mole)	24	36	12	36	24											
C% of MW	41%	49%	27%	41%	27%											

<sup>a</sup>Method detection limit (MDL) = 3 µg/L; reporting detection level (RDL) = 15 µg/L; value in italics < RDL



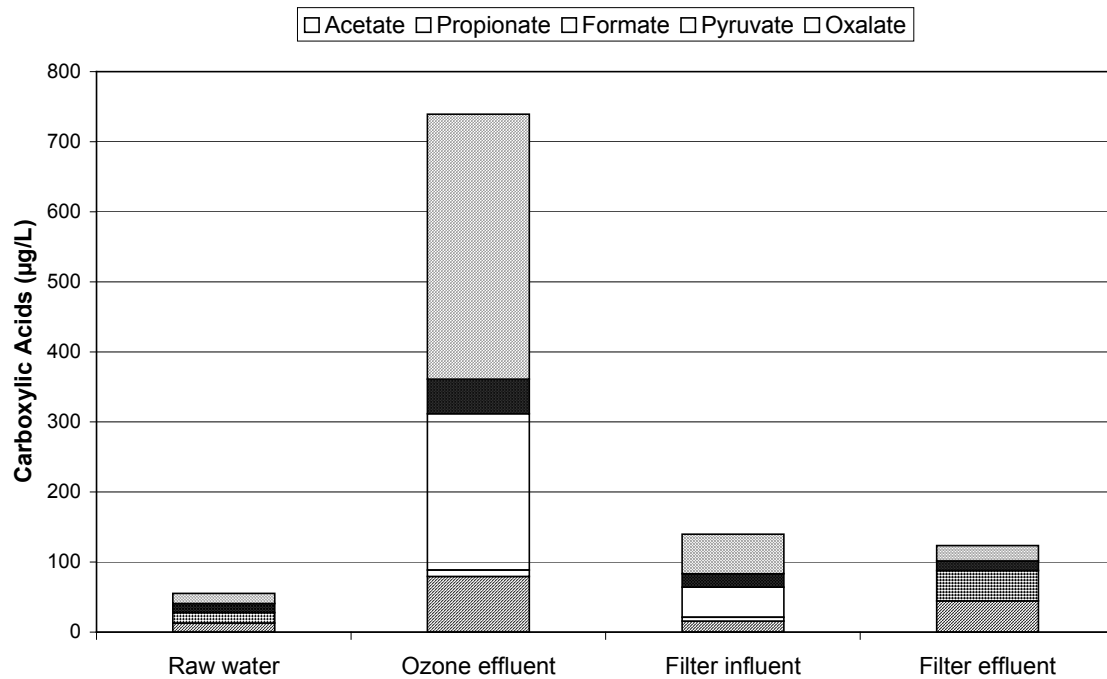
**Figure 3**

**Formation and Removal of AOC at Plant 1: 7/17/01**



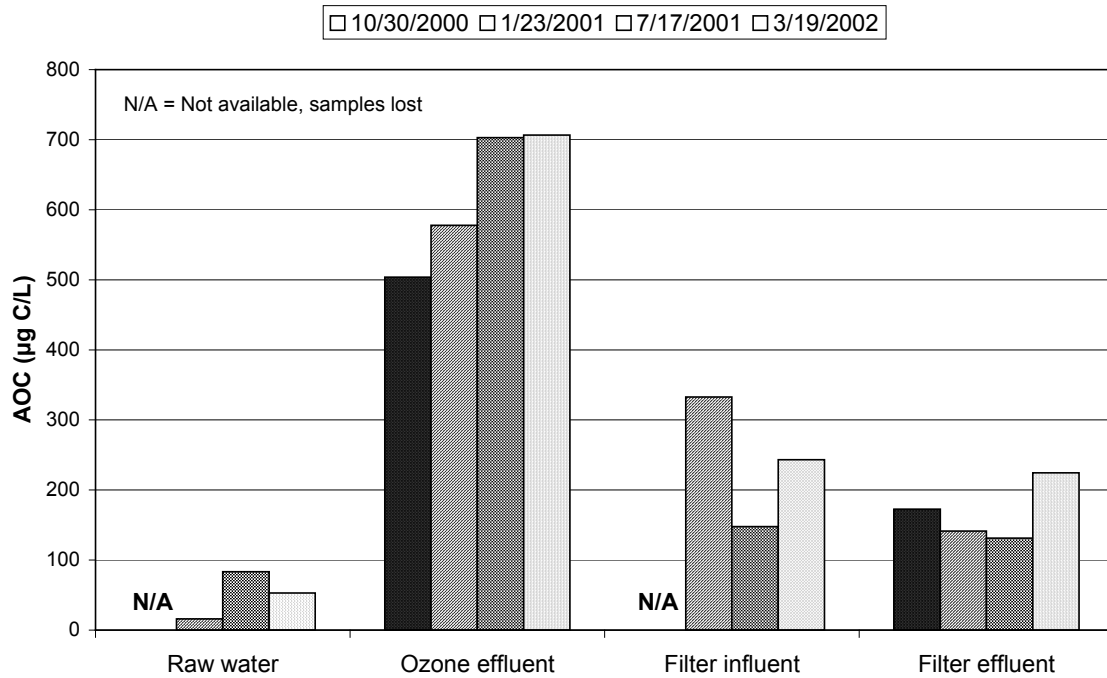
**Figure 4**

**Formation and Removal of Carboxylic Acids at Plant 1: 7/17/01**



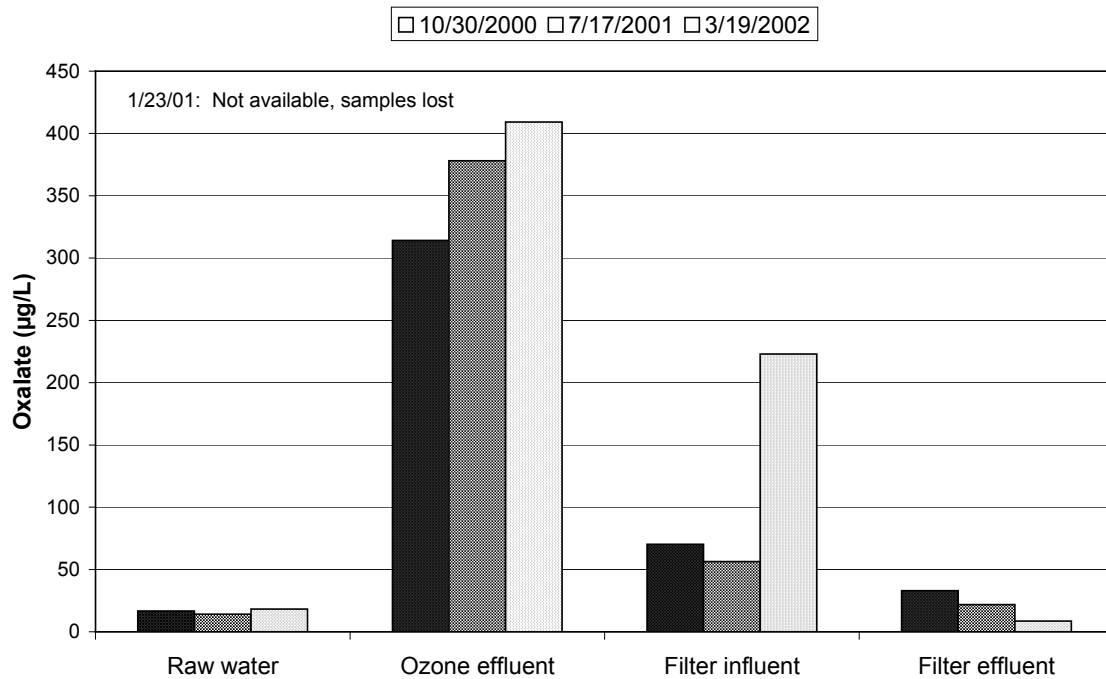
**Figure 5**

**Formation and Removal of AOC at Plant 1**



**Figure 6**

**Formation and Removal of Oxalate at Plant 1**



**Table 10. DBP results at plant 1 (10/30/00)**

10/30/2000	MRL <sup>a</sup>	Plant 1 <sup>b</sup>						
Compound	µg/L	Raw	O <sub>3</sub> Eff	Clear. Eff	Fin. Water	SDS	DS/Ave.	DS/Max.
<u>Halomethanes</u>								
Chloromethane	0.15	ND <sup>d</sup>	ND	ND	ND	ND	ND	
Bromomethane	0.20	ND	ND	ND	ND	ND	ND	
Bromochloromethane	0.14	ND	ND	ND	ND	ND	ND	
Dibromomethane	0.11	ND	ND	ND	ND	ND	ND	
Chloroform <sup>e</sup>	0.1	ND	0.7	1	1	2	8	4
Bromodichloromethane <sup>e</sup>	0.1	ND	0.7	1	3	3	3	4
Dibromochloromethane <sup>e</sup>	0.19	ND	1	4	8	8	7	11
Bromoform <sup>e</sup>	0.14	ND	0.2	2	4	4	3	5
THM4 <sup>f</sup>		ND	3	8	16	17	21	24
Dichloriodomethane	0.5	ND	ND	NR <sup>g</sup>	NR	1	1	NR
Bromochloriodomethane	0.5	ND	NR	NR	NR	NR	NR	NR
Dibromiodomethane	0.5	ND	ND	ND	NR	NR	NR	NR
Chlorodiiodomethane	0.59	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.53	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.22	ND	NR	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND	ND	ND	ND	ND	ND	
Tribromochloromethane	0.1	ND	ND	ND	0.1	0.1	ND	0.1
<u>Haloacetic acids</u>								
Monochloroacetic acid <sup>e</sup>	2			ND	ND	ND	ND	
Monobromoacetic acid <sup>e</sup>	1			ND	ND	ND	ND	
Dichloroacetic acid <sup>e</sup>	1			ND	1.3	1.8	5.8	
Bromochloroacetic acid <sup>e</sup>	1			ND	1.6	2.0	2.2	
Dibromoacetic acid <sup>e</sup>	1			ND	2.1	2.9	2.1	
Trichloroacetic acid <sup>e</sup>	1			ND	ND	ND	1.8	
Bromodichloroacetic acid	1			ND	ND	ND	ND	
Dibromochloroacetic acid	1			ND	ND	ND	ND	
Tribromoacetic acid	2			ND	ND	ND	ND	
HAA5 <sup>h</sup>				ND	3.4	4.7	10	
HAA9 <sup>i</sup>				ND	5.0	6.7	12	
DXAA <sup>j</sup>				ND	5.0	6.7	10	
TXAA <sup>k</sup>				ND	ND	ND	1.8	
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>e</sup>	0.1	ND	ND	ND	0.2	0.2	0.4	0.3
Bromochloroacetonitrile <sup>e</sup>	0.1	ND	ND	0.2	0.4	0.4	0.4	0.6
Dibromoacetonitrile <sup>e</sup>	0.11	ND	ND	0.3	0.6	0.6	0.4	0.7
Trichloroacetonitrile <sup>e</sup>	0.1	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.16	ND	ND	ND	0.4	0.7	0.4	0.7
Bromochloroacetaldehyde <sup>l</sup>								
Chloral hydrate <sup>e</sup>	0.2	ND	ND	ND	1	2	2	0.6
Tribromoacetaldehyde	0.1	0.2	ND	0.2	0.1	ND	ND	0.2

Table 10 (continued)

10/30/2000	MRL <sup>a</sup>	Plant 1 <sup>b</sup>						
Compound	µg/L	Raw	O <sub>3</sub> Eff	Clear. Eff	Fin. Water	SDS	DS/Ave.	DS/Max.
<u>Halo ketones</u>								
Chloropropanone	0.1	ND	ND	ND	0.2	0.3	ND	0.2
1,1-Dichloropropanone <sup>e</sup>	0.1	ND	ND	ND	ND	0.2	ND	0.2
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	3	ND	ND	ND	ND	ND	ND	
1,1,1-Trichloropropanone <sup>e</sup>	0.1	ND	ND	ND	ND	ND	0.2	0.1
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	0.1
1-Bromo-1,1-dichloropropanone	3	ND	ND	ND	ND	ND	ND	
1,1,1-Tribromopropanone	3	ND	ND	ND	ND	ND	ND	
1,1,3-Tribromopropanone	3	ND	ND	ND	ND	ND	ND	
1,1,3,3-Tetrachloropropanone	0.1	ND	ND	1	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>								
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	3	ND	ND	ND	ND	ND	ND	
Dibromonitromethane	0.11	ND	ND	ND	ND	ND	ND	ND
Chloropicrin <sup>e</sup>	0.1	ND	ND	ND	0.2	0.3	0.2	0.2
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	1.9	ND	ND	ND	ND	ND	ND	
Methyl <i>tertiary</i> butyl ether	0.16	0.9	0.6	0.6	0.8	0.7	0.4	
Benzyl chloride	0.5-3	ND	ND	ND	NR	NR	NR	NR

<sup>a</sup>MRL = Minimum reporting level, which equals method detection limit (MDL) or lowest calibration standard or concentration of blank

<sup>b</sup>Plant 1 sampled at (1) raw water, (2) ozone contactor effluent, (3) clearwell effluent, (4) finished water, (5) SDS testing of finished water, (6) distribution system at average detention time and (7) at maximum detention time.

<sup>c</sup>Plant 2 sampled at (1) filter influent, (2) effluent of treated water tank, (3) finished water, (4) SDS testing of finished water, (5) distribution system at average detention time and (6) at maximum detention time.

<sup>d</sup>ND = Not detected at or above MRL

<sup>e</sup>DBP in the Information Collection Rule (ICR) (note: some utilities collected data for all 9 haloacetic acids for the ICR, but monitoring for only 6 haloacetic acids was required)

<sup>f</sup>THM4 = Sum of 4 THMs (chloroform, bromodichloromethane, dibromochloromethane, bromoform)

<sup>g</sup>NR = Not reported, due to interference problem on gas chromatograph or to problem with quality assurance

<sup>h</sup>HAA5 = Sum of 5 haloacetic acids (monochloro-, monobromo-, dichloro-, dibromo-, trichloroacetic acid)

<sup>i</sup>HAA9 = Sum of 9 haloacetic acids

<sup>j</sup>DXAA = Sum of dihaloacetic acids (dichloro-, bromochloro-, dibromoacetic acid)

<sup>k</sup>TXAA = Sum of trihaloacetic acids (trichloro-, bromodichloro-, dibromochloro-, tribromoacetic acid)

<sup>l</sup>Bromochloroacetaldehyde and chloral hydrate co-eulter; result = sum of 2 DBPs

<sup>m</sup><3: Concentration less than MRL of 3 µg/L

**Table 11. DBP results at plant 2 (10/30/00)**

10/30/2000	MRL <sup>a</sup>	Plant 2 <sup>c</sup>					
Compound	µg/L	Filt. Inf	Treat. Tank	Fin. Water	SDS	DS/Ave.	DS/Max.
<u>Halomethanes</u>							
Chloromethane	0.15		ND	ND	ND	ND	
Bromomethane	0.20		ND	ND	ND	ND	
Bromochloromethane	0.14		ND	ND	ND	ND	
Dibromomethane	0.11		ND	ND	ND	ND	
Chloroform <sup>e</sup>	0.1	10	11	14	15	14	17
Bromodichloromethane <sup>e</sup>	0.1	8	15	14	17	23	20
Dibromochloromethane <sup>e</sup>	0.19	16	25	25	26	35	31
Bromoform <sup>e</sup>	0.14	4	5	5	5	6	6
THM4 <sup>f</sup>		38	56	58	63	78	74
Dichloriodomethane	0.5	NR	NR	NR	3	4	NR
Bromochloriodomethane	0.5	NR	1	1	1	1	NR
Dibromiodomethane	0.5	NR	NR	NR	NR	1	NR
Chlorodiodomethane	0.59	ND	ND	ND	ND	0.7	ND
Bromodiodomethane	0.53	ND	ND	ND	ND	ND	ND
Iodoform	0.22	NR	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06		ND	ND	ND	ND	
Tribromochloromethane	0.1	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>							
Monochloroacetic acid <sup>e</sup>	2		ND	ND	ND	ND	
Monobromoacetic acid <sup>e</sup>	1		ND	ND	ND	ND	
Dichloroacetic acid <sup>e</sup>	1		9.9	9.5	11	11	
Bromochloroacetic acid <sup>e</sup>	1		9.4	9.1	10	11	
Dibromoacetic acid <sup>e</sup>	1		6.9	6.6	7.1	8.1	
Trichloroacetic acid <sup>e</sup>	1		8.4	7.9	8.6	8.4	
Bromodichloroacetic acid	1		6.0	5.6	3.4	ND	
Dibromochloroacetic acid	1		2.5	2.4	1.6	ND	
Tribromoacetic acid	2		ND	ND	ND	ND	
HAA5 <sup>h</sup>			25	24	27	28	
HAA9 <sup>i</sup>			43	41	42	39	
DXAA <sup>j</sup>			26	25	28	30	
TXAA <sup>k</sup>			17	16	14	8.4	
<u>Haloacetonitriles</u>							
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>e</sup>	0.1	1	2	2	2	2	2
Bromochloroacetonitrile <sup>e</sup>	0.1	1	2	2	2	2	2
Dibromoacetonitrile <sup>e</sup>	0.11	0.8	1	1	1	2	1
Trichloroacetonitrile <sup>e</sup>	0.1	ND	ND	ND	ND	ND	ND
<u>Haloacetaldehydes</u>							
Dichloroacetaldehyde	0.16	0.6	0.9	1	2	1	2
Bromochloroacetaldehyde <sup>l</sup>							
Chloral hydrate <sup>e</sup>	0.2	3	4	4	4	4	5
Tribromoacetaldehyde	0.1	0.5	0.6	0.4	ND	0.3	ND

Table 11 (continued)

10/30/2000	MRL <sup>a</sup>	Plant 2 <sup>c</sup>					
Compound	µg/L	Filt. Inf	Treat. Tank	Fin. Water	SDS	DS/Ave.	DS/Max.
<u>Haloketones</u>							
Chloropropanone	0.1	ND	ND	ND	0.1	0.2	0.2
1,1-Dichloropropanone <sup>e</sup>	0.1	0.4	0.3	0.3	0.4	0.4	0.4
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	3		ND	ND	ND	ND	
1,1,1-Trichloropropanone <sup>e</sup>	0.1	0.9	2	1	0.7	1	0.3
1,1,3-Trichloropropanone	0.1	0.1	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	3		<3 <sup>m</sup>	<3	ND	ND	
1,1,1-Tribromopropanone	3		ND	ND	ND	ND	
1,1,3-Tribromopropanone	3		ND	ND	ND	ND	
1,1,3,3-Tetrachloropropanone	0.1	0.2	0.2	0.2	0.1	0.2	ND
1,1,3,3-Tetrabromopropanone	0.1	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>							
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND
Dichloronitromethane	3		ND	ND	ND	ND	
Dibromonitromethane	0.11	ND	ND	ND	ND	ND	ND
Chloropicrin <sup>e</sup>	0.1	ND	ND	ND	0.2	0.2	0.3
<u>Miscellaneous Compounds</u>							
Methyl ethyl ketone	1.9		ND	ND	ND	ND	
Methyl <i>tertiary</i> butyl ether	0.16		0.9	0.9	0.9	0.9	
Benzyl chloride	0.5-3	NR	NR	NR	NR	NR	NR

**Table 12. Additional target DBP results (µg/L) at the EPA Region 9 treatment plants (10/30/00)**

10/30/00	Plant 1 <sup>a</sup>					Plant 2 <sup>b</sup>				
Compound	Raw	OE	FE	PE	DS	Raw	FI	TT	PE	DS
Monochloroacetaldehyde	0	0	0	0	0	0	0.1	0.1	0.1	0.2
Dichloroacetaldehyde	0	0	0	0.6	0.7	0	0.9	1.1	1.4	1.7
Bromochloroacetaldehyde	0	0	0	1.0	1.3	0	1.7	1.9	1.3	1.1
3,3-Dichloropropenoic acid	0	0	0	0.1	0.1		0.3	0.4	0.7	0.2
Bromochloromethylacetate	0.5	0.1	0.1	0.1	0.1		0	0	0	0
2,2-Dichloroacetamide	0	0	0	0.2	0.3		0	0	0.8	1.4
TOX (µg/L as Cl <sup>-</sup> )	NA <sup>c</sup>	NA	10.2	75.5	109		NA	NA	199	135
Cyanoformaldehyde	<0.1	<0.1	<0.1	0.2	0.2		0.1	<0.1	0.3	0.3
5-Keto-1-hexanal	<0.4	<0.4	<0.4	<0.4	<0.4		<0.4	<0.4	<0.4	<0.4
6-Hydroxy-2-hexanone	<0.4	<0.4	<0.4	<0.4	<0.4		<0.4	<0.4	<0.4	<0.4
Dimethylglyoxal	<0.4	1.3	1.1	<0.4	<0.4		<0.4	<0.4	<0.4	<0.4
<i>trans</i> -2-Hexenal	<0.5	<0.5	<0.5	<0.5	<0.5		<0.5	<0.5	<0.5	<0.5

<sup>a</sup>Plant 1 sampled at (1) raw water, (2) ozone contactor effluent (OE), (3) filter effluent (FE), (4) finished water at plant effluent (PE), and (5) distribution system (DS) at average detention time.

<sup>b</sup>Plant 2 sampled at (1) filter influent (FI), (2) effluent of treated water tank (TT), (3) finished water at PE, and (4) DS at average detention time.

<sup>c</sup>NA = Not available

**Table 13. DBP results at plant 1 (1/23/01)**

1/23/2001	MRL <sup>a</sup>	Plant 1 <sup>n</sup>							
Compound	µg/L	Raw	O <sub>3</sub> Eff	Clear. Eff	Fin. Water	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Halomethanes</u>									
Chloromethane	0.15	ND <sup>d</sup>	ND	ND	ND	ND		ND	
Bromomethane	0.20	ND	ND	ND	ND	ND		ND	
Bromochloromethane	0.14	ND	ND	ND	ND	ND		ND	
Dibromomethane	0.11	ND	ND	ND	ND	ND		ND	
Chloroform <sup>e</sup>	0.1	ND	0.2	0.5	NR <sup>g</sup>	2	NR	1	NR
Bromodichloromethane <sup>e</sup>	0.1	ND	1	2	NR	7	NR	6	NR
Dibromochloromethane <sup>e</sup>	0.12	ND	1	4	NR	16	NR	20	NR
Bromoform <sup>e</sup>	0.12	ND	0.5	3	NR	20	NR	30	NR
THM4 <sup>f</sup>		ND	3	10	NR	45	NR	57	NR
Dichloriodomethane	0.25	ND	ND	ND	0.2	0.3	NR	0.2	NR
Bromochloriodomethane	0.20	ND	ND	ND	ND	0.2	NR	ND	NR
Dibromiodomethane	0.64	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.60	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.70	ND	1	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06	ND	ND	ND	ND	ND		ND	
<u>Haloacetic acids</u>									
Monochloroacetic acid <sup>e</sup>	2			ND	ND	ND		ND	
Monobromoacetic acid <sup>e</sup>	1			1.1	1.4	1.2		1.4	
Dichloroacetic acid <sup>e</sup>	1			2.1	2.0	3.6		2.4	
Bromochloroacetic acid <sup>e</sup>	1			3.0	3.0	7.0		4.9	
Dibromoacetic acid <sup>e</sup>	1			14	13	13		11	
Trichloroacetic acid <sup>e</sup>	1			ND	ND	1.0		ND	
Bromodichloroacetic acid	1			1.0	ND	1.4		ND	
Dibromochloroacetic acid	1			2.2	1.4	2.1		1.4	
Tribromoacetic acid	2			ND	ND	ND		ND	
HAA5 <sup>h</sup>				17	16	19		15	
HAA9 <sup>i</sup>				23	21	29		21	
DXAA <sup>j</sup>				19	18	24		18	
TXAA <sup>k</sup>				3.2	1.4	4.5		1.4	
<u>Haloacetonitriles</u>									
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>e</sup>	0.1	ND	ND	0.1	0.1	0.2	0.4	0.2	0.2
Bromochloroacetonitrile <sup>e</sup>	0.1	ND	ND	0.3	0.3	0.3	1	0.9	0.9
Dibromoacetonitrile <sup>e</sup>	0.10	ND	ND	0.6	0.7	0.7	2	2	2
Trichloroacetonitrile <sup>e</sup>	0.1	ND	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetaldehydes</u>									
Dichloroacetaldehyde	0.16	ND	0.3	0.8	NR	0.8	1	2	2
Bromochloroacetaldehyde	0.1	ND	0.6	3	3	3	6	7	6
Chloral hydrate <sup>e</sup>	0.1	ND	0.2	0.1	NR	0.2	0.3	0.2	0.2
Tribromoacetaldehyde	0.1	ND	0.1	1	NR	0.5	0.4	0.2	ND



Table 13 (continued)

1/23/2001	MRL	Plant 1							
Compound	µg/L	Raw	O <sub>3</sub> Eff	Clear. Eff	Fin. Water	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Haloketones</u>									
Chloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone <sup>e</sup>	0.10	ND	0.2	0.3	0.2	0.3	0.2	0.1	0.2
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	N/A <sup>p</sup>	NR		NR	NR	NR		NR	
1,1,1-Trichloropropanone <sup>e</sup>	0.10	ND	ND	0.2	0.3	0.2	0.2	0.2	ND
1,1,3-Trichloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	N/A	NR		NR	NR	NR		NR	
1,1,1-Tribromopropanone	N/A	NR		NR	NR	NR		NR	
1,1,3-Tribromopropanone	N/A	NR		NR	NR	NR		NR	
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	N/A	NR		NR	NR	NR		NR	
1,1,3,3-Tetrabromopropanone	0.5	ND	ND	0.2-0.6 <sup>q</sup>	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>									
Bromonitromethane	0.1	ND	ND	0.1	0.1	0.1	0.2	0.2	0.2
Dichloronitromethane	N/A	NR		NR	NR	NR		NR	
Bromochloronitromethane	N/A	NR		NR	NR	NR		NR	
Dibromonitromethane	0.10	ND	ND	0.1-0.2 <sup>q</sup>	0.1-0.2	0.1-0.2	0.2-0.3	0.1-0.2	ND
Chloropicrin <sup>e</sup>	0.1	ND	ND	ND	ND	ND	0.2	0.2	0.4
<u>Miscellaneous Compounds</u>									
Methyl ethyl ketone	1.9	ND	ND	ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.16	0.3	0.2	0.2	0.2	0.2		0.2	
Benzyl chloride	2	ND	ND	ND	ND	ND	ND	ND	ND

<sup>n</sup>Plant 1 sampled at (1) raw water, (2) ozone contactor effluent, (3) clearwell effluent, (4) finished water, (5) SDS testing of finished water at average detention time and (6) at maximum detention time, and (7) distribution system at average detention time and (8) at maximum detention time.

<sup>o</sup>Plant 2 sampled at (1) filter effluent, (2) effluent of treated water tank, (3) finished water, (4) SDS testing of finished water at average detention time and (5) at maximum detention time, and (6) distribution system at average detention time and (7) at maximum detention time.

<sup>p</sup>N/A = Not applicable

<sup>q</sup>Spike recovery >>100%; range of values represents reported values and values corrected for recovery

**Table 14. DBP results at plant 2 (1/23/01)**

1/23/2001	MRL	Plant 2°						
Compound	µg/L	Filt. Eff	Treat. Tank	Fin. Water	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Halomethanes</u>								
Chloromethane	0.15		ND	ND	ND		ND	
Bromomethane	0.20		ND	ND	ND		ND	
Bromochloromethane	0.14		ND	ND	ND		ND	
Dibromomethane	0.11		ND	ND	ND		ND	
Chloroform <sup>e</sup>	0.1	NR	8	11	18	NR	17	NR
Bromodichloromethane <sup>e</sup>	0.1	NR	20	30	40	NR	40	NR
Dibromochloromethane <sup>e</sup>	0.12	NR	30	40	50	NR	50	NR
Bromoform <sup>e</sup>	0.12	NR	18	18	19	NR	20	NR
THM4 <sup>f</sup>		NR	76	99	127	NR	127	NR
Dichloriodomethane	0.25	NR	0.5	0.6	0.4	NR	0.5	NR
Bromochloriodomethane	0.20	NR	0.6	0.8	0.4	NR	0.5	NR
Dibromiodomethane	0.64	ND	ND	0.6	0.8	ND	ND	0.8
Chlorodiiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.60	0.6	ND	ND	ND	ND	ND	ND
Iodoform	0.70	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.06		ND	ND	ND		ND	
<u>Haloacetic acids</u>								
Monochloroacetic acid <sup>e</sup>	2		ND	ND	ND		ND	
Monobromoacetic acid <sup>e</sup>	1		1.2	1.2	1.3		1.4	
Dichloroacetic acid <sup>e</sup>	1		14	14	15		15	
Bromochloroacetic acid <sup>e</sup>	1		19	18	19		19	
Dibromoacetic acid <sup>e</sup>	1		18	18	20		20	
Trichloroacetic acid <sup>e</sup>	1		9.7	8.6	8.6		9.1	
Bromodichloroacetic acid	1		16	15	15		15	
Dibromochloroacetic acid	1		15	15	14		15	
Tribromoacetic acid	2		3.9	3.6	3.3		3.5	
HAA5 <sup>h</sup>			43	42	45		46	
HAA9 <sup>i</sup>			97	93	96		98	
DXAA <sup>j</sup>			51	50	54		54	
TXAA <sup>k</sup>			45	42	41		43	
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>e</sup>	0.1	2	2	2	2	2	2	2
Bromochloroacetonitrile <sup>e</sup>	0.1	2	3	3	3	3	3	3
Dibromoacetonitrile <sup>e</sup>	0.10	2	3	2	3	3	3	3
Trichloroacetonitrile <sup>e</sup>	0.1	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.16	1	2	2	3	4	3	3
Bromochloroacetaldehyde	0.1	4	4	4	4	3	4	4
Chloral hydrate <sup>e</sup>	0.1	0.6	1	1	2	2	2	2
Tribromoacetaldehyde	0.1	1	3	3	1	0.2	1	0.5

Table 14 (continued)

1/23/2001	MRL	Plant 2						
Compound	µg/L	Filt. Eff	Treat. Tank	Fin. Water	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Haloketones</u>								
Chloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone <sup>e</sup>	0.10	0.4	0.4	0.4	0.4	0.5	0.6	0.6
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	N/A		NR	NR	NR		NR	
1,1,1-Trichloropropanone <sup>e</sup>	0.10	1	1	1	1	0.7	1	1
1,1,3-Trichloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	N/A		NR	NR	NR		NR	
1,1,1-Tribromopropanone	N/A		NR	NR	NR		NR	
1,1,3-Tribromopropanone	N/A		NR	NR	NR		NR	
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	N/A		NR	NR	NR		NR	
1,1,3,3-Tetrabromopropanone	0.5	0.7-2	0.5-2	0.6-2	0.3-0.9	ND	ND	ND
<u>Halonitromethanes</u>								
Bromonitromethane	0.1	0.2	0.2	0.1	ND	ND	ND	ND
Dichloronitromethane	N/A		NR	NR	NR		NR	
Bromochloronitromethane	N/A		NR	NR	NR		NR	
Dibromonitromethane	0.10	0.2-0.4	0.2-0.5	0.2-0.4	0.2-0.3	<0.1-0.1	ND	ND
Chloropicrin <sup>e</sup>	0.1	0.2	0.3	ND	0.5	0.8	1	2
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	1.9		ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.16		0.3	0.3	0.3		0.3	
Benzyl chloride	2	ND	ND	ND	ND	ND	ND	ND

**Table 15. Occurrence of other DBPs<sup>a</sup> at plant 1 (1/23/01)**

<u>Compound</u>	<u>OE</u>	<u>PE</u>	<u>Compound</u>	<u>OE</u>	<u>PE</u>
<u>Halomethanes</u>			<u>Haloaldehydes</u>		
Bromochloromethane	x	-	Dichloroacetaldehyde	x	-
Dibromomethane	x	-	Bromochloroacetaldehyde	x	x
<i>Bromodichloromethane<sup>b</sup></i>	x	x	Trichloroacetaldehyde	x	-
<i>Dibromochloromethane</i>	x	x	Tribromoacetaldehyde	x	-
<i>Bromoform</i>	x	-	2-Bromo-2-methylpropanal	-	x
<i>Dichloroiodomethane</i>	-	x	<u>Haloketones</u>		
<i>Bromochloroiodomethane</i>	-	x	1,1-Dichloropropanone	x	x
<i>Dibromoiodomethane</i>	-	x	1-Bromo-1-chloropropanone	-	x
<u>Haloacids</u>			<i>1,1-Dibromopropanone</i>	x	x
<i>Bromoacetic acid</i>	-	x	1,1,1-Trichloropropanone	x	x
<i>Dichloroacetic acid</i>	-	x	1,1,3-Trichloropropanone	-	x
<i>Bromochloroacetic acid</i>	x	x	1-Bromo-1,1-dichloropropanone	-	x
<i>Dibromoacetic acid</i>	x	x	<i>1,1,1-Tribromopropanone</i>	-	x
<i>Dibromochloroacetic acid</i>	-	x	1,1,3,3-Tetrachloropropanone	x	x
<i>Tribromoacetic acid</i>	-	x	<i>1,1,3-Tribromo-3-chloropropanone</i>	-	x
<i>2,2-Dibromopropanoic acid</i>	-	x	<i>1,1,3,3-Tetrabromopropanone</i>	x	x
<i>3,3-Dibromopropenoic acid</i>	-	x	<u>Halonitromethanes</u>		
<i>cis-2,3-Dibromopropenoic acid</i>	-	x	Bromonitromethane	-	x
<i>Tribromopropenoic acid</i>	-	x	Dibromonitromethane	-	x
<i>2-Bromobutanoic acid</i>	-	x	<u>Miscellaneous Halogenated DBPs</u>		
<i>trans-4-Bromo-2-butenic acid</i>	-	x	Chlorobenzene	x	x
<i>cis-4-Bromo-2-butenic acid</i>	-	x	Tribromophenol	-	x
<i>2,3-Dibromo-2-butenic acid</i>	-	x	<u>Non-halogenated DBPs</u>		
<i>Bromodichloro-butenic acid<sup>c</sup></i>	-	x	<i>Glyoxal</i>	x	x
<i>Bromochloro-4-oxopentanoic acid</i>	-	x	<i>Pentanoic acid</i>	x	x
<i>3,3-Dibromo-4-oxopentanoic acid</i>	-	x	<i>Hexanoic acid</i>	x	x
<i>cis-2-Bromo-butenedioic acid</i>	-	x	<i>Heptanoic acid</i>	x	x
<i>trans-2,3-Dibromo-butenedioic acid</i>	-	x	<i>Octanoic acid</i>	x	x
<i>cis-2-Bromo-3-methylbutenedioic acid</i>	-	x	<i>Nonanoic acid</i>	x	x
	-	x	<i>Decanoic acid</i>	x	x
<u>Haloacetonitriles</u>			<i>Undecanoic acid</i>	-	x
Dichloroacetonitrile	-	x	<i>Dodecanoic acid</i>	-	x
<i>Bromochloroacetonitrile</i>	-	x	<i>Tetradecanoic acid</i>	x	x
<i>Dibromoacetonitrile</i>	-	x	<i>Pentadecanoic acid</i>	x	x
			<i>Hexadecanoic acid</i>	x	x
			<i>Octadecanoic acid</i>	x	x
			<i>Ethanedioic acid</i>	-	x
			<i>Octanedioic acid</i>	-	x
			<i>Nonanedioic acid</i>	x	x

<sup>a</sup>DBPs detected by broadscreen gas chromatography/mass spectrometry (GC/MS) technique

<sup>b</sup>Compounds listed in italics were confirmed through the analysis of authentic standards; haloacids and non-halogenated carboxylic acids identified as their methyl esters.

<sup>c</sup>Exact isomer not known

**Table 16. DBP results at plant 1 (7/17/01)**

07/17/2001	MRL <sup>a</sup>	Plant 1 <sup>n</sup>							
Compound	µg/L	Raw	O <sub>3</sub> Eff	Clear. Eff	Fin. Water	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Halomethanes</u>									
Chloromethane	0.2	ND <sup>d</sup>	ND	ND	ND	ND		ND	
Bromomethane	0.2	ND	ND	ND	ND	ND		ND	
Bromochloromethane	0.5	ND	ND	ND	ND	ND		ND	
Dibromomethane	0.5	ND	ND	ND	ND	ND		ND	
Chloroform <sup>e</sup>	0.1	ND	0.1	0.2	0.4	1	1	0.3	0.4
Bromodichloromethane <sup>e</sup>	0.1	ND	0.1	0.7	2	3	3	2	2
Dibromochloromethane <sup>e</sup>	0.1	ND	ND	1	4	4	NR <sup>g</sup>	3	NR
Bromoform <sup>e</sup>	0.11	ND	ND	0.8	3	3	3	3	3
THM4 <sup>f</sup>		ND	0.2	3	9	11	NR	8	NR
Dichloriodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Bromochloriodomethane	0.25	ND	ND	ND	ND	ND	NR	ND	NR
Dibromiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.1-0.5	ND	ND	0.2	ND	0.3	ND	ND	ND
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND	ND	ND	ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>									
Monochloroacetic acid <sup>e</sup>	2			ND	ND	ND		ND	
Monobromoacetic acid <sup>e</sup>	1			ND	ND	ND		ND	
Dichloroacetic acid <sup>e</sup>	1			1.1	2.2	4.8		2.2	
Bromochloroacetic acid <sup>e</sup>	1			2.4	2.2	3.6		3.8	
Dibromoacetic acid <sup>e</sup>	1			4.2	3.6	4.3		6.4	
Trichloroacetic acid <sup>e</sup>	1			ND	ND	1.2		ND	
Bromodichloroacetic acid	1			ND	ND	1.1		ND	
Dibromochloroacetic acid	1			ND	ND	ND		ND	
Tribromoacetic acid	2			ND	ND	ND		ND	
HAA5 <sup>h</sup>				5.3	5.8	10		9	
HAA9 <sup>i</sup>				7.7	8.0	15		12	
DXAA <sup>j</sup>				7.7	8.0	13		12	
TXAA <sup>k</sup>				ND	ND	2.3		ND	
<u>Haloacetonitriles</u>									
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>e</sup>	0.10	ND	ND	ND	0.1	0.2	0.2	0.1	ND
Bromochloroacetonitrile <sup>e</sup>	0.1	ND	ND	ND	0.3	0.1	0.3	0.3	0.2
Dibromoacetonitrile <sup>e</sup>	0.14	ND	ND	0.6	0.6	0.6	0.6	0.6	0.4
Trichloroacetonitrile <sup>e</sup>	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND	ND		ND				ND
Dibromochloroacetonitrile	0.5	ND	ND		ND				ND
Tribromoacetonitrile	0.5	ND	ND		ND				ND
<u>Haloacetaldehydes</u>									
Dichloroacetaldehyde	0.22	ND	ND	2	0.2	1	2	0.7	2
Bromochloroacetaldehyde	0.1	ND	ND	1	0.4	ND	ND	ND	0.1
Chloral hydrate <sup>e</sup>	0.1	ND	ND	2	ND	ND	ND	ND	ND
Tribromoacetaldehyde	0.1	ND	ND	2	0.1	ND	ND	ND	ND

Table 16 (continued)

07/17/2001	MRL <sup>a</sup>	Plant 1 <sup>n</sup>							
Compound	µg/L	Raw	O <sub>3</sub> Eff	Clear. Eff	Fin. Water	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Haloketones</u>									
Chloropropanone	0.1	ND	ND	0.1	0.1	0.1	ND	0.1	ND
1,1-Dichloropropanone <sup>e</sup>	0.10	ND	ND	0.2	0.2	0.3	0.3	0.2	0.2
1,3-Dichloropropanone	0.1	ND	ND	0.5	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.10	ND	ND	0.3	0.1	ND	ND	ND	ND
1,1,1-Trichloropropanone <sup>e</sup>	0.1	ND	ND	0.5	0.1	ND	ND	ND	ND
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	0.4	ND	ND	ND	ND	ND
1,1,1-Tribromopropanone	0.29	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.14	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>									
Bromonitromethane	0.1	ND	ND	ND	0.2	ND	0.1	0.1	0.1
Dichloronitromethane	0.1	ND	ND	ND	0.1	0.2	0.2	ND	0.2
Bromochloronitromethane	0.1	ND	ND	ND	0.2	0.1	0.1	0.2	0.1
Dibromonitromethane	0.10	ND	ND	0.1	0.5	0.2	0.2	0.4	0.2
Chloropicrin <sup>e</sup>	0.1	0.1	0.2	0.1	ND	0.2	0.1	0.1	0.2
Bromodichloronitromethane	0.5	ND	ND		0.7				0.9
Dibromochloronitromethane	0.5	ND	ND		1.5				1.7
Bromopicrin	0.5	ND	ND		2.5				2.8
<u>Miscellaneous Compounds</u>									
Methyl ethyl ketone	0.5	ND	1	ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.2	ND	ND	ND	ND	ND		ND	
1,1,2,2-Tetrabromo-2-chloroethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Benzyl chloride	0.25	ND	NR	ND	ND	ND	NR	ND	NR

<sup>a</sup><0.5 = Detected by GC/MS below its MRL of 0.5 µg/L; interference problem with GC/ECD analysis

**Table 17. DBP results at plant 2 (7/17/01)**

07/17/2001	MRL	Plant 2 <sup>o</sup>						
Compound	µg/L	Filt. Eff	Treat. Tank	Fin. Water	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Halomethanes</u>								
Chloromethane	0.2		ND	ND	ND		ND	
Bromomethane	0.2		ND	ND	ND		ND	
Bromochloromethane	0.5		ND	ND	ND		ND	
Dibromomethane	0.5		ND	ND	ND		ND	
Chloroform <sup>e</sup>	0.1	5	6	7	7	9	8	8
Bromodichloromethane <sup>e</sup>	0.1	9	11	13	15	16	16	16
Dibromochloromethane <sup>e</sup>	0.1	NR	7	10	11	NR	11	NR
Bromoform <sup>e</sup>	0.11	2	2	2	2	2	2	2
THM4 <sup>f</sup>		NR	26	32	35	NR	37	NR
Dichloroiodomethane	0.5	5	4	4	3	0.6	3	2
Bromochloroiodomethane	0.25	NR	1	1	1	NR	1	NR
Dibromoiodomethane	0.5	NR	<0.5 <sup>f</sup>	<0.5	<0.5	ND	0.7	NR
Chlorodiiodomethane	0.1-0.5	0.4	<0.5	<0.5	<0.5	ND	0.5	NR
Bromodiiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.5	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2		ND	ND	ND		ND	
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid <sup>e</sup>	2		ND	ND	ND		ND	
Monobromoacetic acid <sup>e</sup>	1		ND	ND	ND		ND	
Dichloroacetic acid <sup>e</sup>	1		12	12	12		13	
Bromochloroacetic acid <sup>e</sup>	1		12	11	11		12	
Dibromoacetic acid <sup>e</sup>	1		6.2	6.2	6.2		6.6	
Trichloroacetic acid <sup>e</sup>	1		9.2	9.0	7.5		9.3	
Bromodichloroacetic acid	1		7.9	7.8	7.0		8.3	
Dibromochloroacetic acid	1		3.7	3.6	3.0		3.8	
Tribromoacetic acid	2		ND	ND	ND		ND	
HAA5 <sup>h</sup>			27	27	26		29	
HAA9 <sup>i</sup>			51	50	47		53	
DXAA <sup>j</sup>			30	29	29		32	
TXAA <sup>k</sup>			21	20	18		21	
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.1	ND	0.1	0.1	0.1	0.1	0.1	0.1
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>e</sup>	0.10	1	2	2	2	2	2	2
Bromochloroacetonitrile <sup>e</sup>	0.1	1	2	2	2	2	2	2
Dibromoacetonitrile <sup>e</sup>	0.14	1	2	2	2	2	1	2
Trichloroacetonitrile <sup>e</sup>	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5			ND	ND			ND
Dibromochloroacetonitrile	0.5			ND	ND			ND
Tribromoacetonitrile	0.5			ND	ND			ND
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.22	2	1	1	0.9	1	1	2
Bromochloroacetaldehyde	0.1	2	1	1	1	0.6	1	1
Chloral hydrate <sup>e</sup>	0.1	1	2	2	2	1	2	2
Tribromoacetaldehyde	0.1	0.3	0.2	0.2	0.1	ND	0.1	0.1

Table 17 (continued)

07/17/2001	MRL	Plant 2°						
Compound	µg/L	Filt. Eff	Treat. Tank	Fin. Water	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<b>Haloketones</b>								
Chloropropanone	0.1	ND	ND	0.1	0.1	0.1	0.1	0.1
1,1-Dichloropropanone <sup>e</sup>	0.10	0.7	0.8	0.7	0.5	0.5	0.6	0.7
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.10	0.6	0.3	0.3	0.2	ND	0.2	0.1
1,1,1-Trichloropropanone <sup>e</sup>	0.1	0.7	1	1	0.9	0.2	0.8	0.7
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	NR	1	1	0.3	ND	ND	ND
1,1,1-Tribromopropanone	0.29	ND	ND	ND	ND	ND	ND	ND
1,1,3-Tribromopropanone	0.14	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
<b>Halonitromethanes</b>								
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	0.2	0.2	0.2	0.2	0.1	0.2	0.1
Bromochloronitromethane	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Dibromonitromethane	0.10	0.1	0.1	0.1	0.1	ND	ND	ND
Chloropicrin <sup>e</sup>	0.1	0.1	0.2	0.2	0.2	0.1	0.1	0.2
Bromodichloronitromethane	0.5			0.8	0.6			0.8
Dibromochloronitromethane	0.5			1.0	0.8			0.9
Bromopicrin	0.5			ND	ND			ND
<b>Miscellaneous Compounds</b>								
Methyl ethyl ketone	0.5		ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.2		ND	ND	ND		ND	
1,1,2,2-Tetrabromo-2-chloroethane	0.1	ND	ND	ND	ND	ND	ND	ND
Benzyl chloride	0.25	NR	ND	ND	ND	NR	ND	NR



**Table 18. Additional target DBP results (µg/L) at the EPA Region 9 treatment plants (7/17/01)**

7/17/01	Plant 1 <sup>a</sup>						Plant 2 <sup>a</sup>				
Compound	Raw	OE	FE	PE	DS	SDS	FI	TT	PE	DS	SDS
Monochloroacetaldehyde											
Dichloroacetaldehyde											
Bromochloroacetaldehyde											
3,3-Dichloropropenoic acid	0	0	0	0	0	0	0	0	0	0	0
Bromochloromethylacetate	0	0	0	0	0	0	0	0	0	0	0
2,2-Dichloroacetamide	0	0	0	0	0	0	0	0	0	0	0
TOX (µg/L as Cl <sup>-</sup> )	NA	NA	10.2	21.1	25.3	43.2	75.6	84.5	91.3	106	114
Cyanoformaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
5-Keto-1-hexanal	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
6-Hydroxy-2-hexanone	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
Dimethylglyoxal	<0.4	0.8	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4
<i>trans</i> -2-Hexenal	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4

<sup>a</sup>SDS testing of finished water at maximum detention time

**Table 19. Halogenated furanone results (µg/L) at the EPA Region 9 treatment plants (7/17/01)**

7/17/01	Plant 1		Plant 2	
Compound	FE	PE	FE	DS
Mucochloric acid (ring)	<0.04	<0.04	<0.04	<0.04
Mucochloric acid (open)	<0.04	<0.04	0.07	<0.04
MX	<0.04	<0.04	0.12	0.07
ZMX	<0.04	<0.04	0.05	<0.04
EMX	<0.04	<0.04	<0.04	<0.04

**Table 20. DBP results at plant 1 (3/19/02)**

<b>03/19/2002</b>	<b>MRL<sup>a</sup></b>	<b>Plant 1<sup>n</sup></b>							
<b>Compound</b>	<b>µg/L</b>	<b>Raw</b>	<b>O<sub>3</sub> Eff</b>	<b>Clear. Eff</b>	<b>Fin. Water</b>	<b>DS/Ave</b>	<b>DS/Max</b>	<b>SDS/Ave</b>	<b>SDS/Max</b>
<u>Halomethanes</u>									
Chloromethane	0.2	ND <sup>d</sup>	ND	ND	ND	ND		ND	
Bromomethane	0.2	ND	ND	ND	ND	ND		ND	
Bromochloromethane	0.5	ND	ND	ND	ND	ND		ND	
Dibromomethane	0.5	ND	ND	ND	ND	ND		ND	
Chloroform <sup>e</sup>	0.2	ND	1	2	2	3	NR <sup>g</sup>	2	2
Bromodichloromethane <sup>e</sup>	0.2	ND	1	2	3	4	NR	4	5
Dibromochloromethane <sup>e</sup>	0.2	ND	0.4	2	3	4	NR	4	7
Bromoform <sup>e</sup>	0.2	ND	ND	0.6	0.8	2	NR	2	1
THM4 <sup>f</sup>		ND	2	7	9	13	NR	12	15
Dichloroiodomethane	0.25	ND	0.3	ND	NR	ND	NR	ND	0.4
Bromochloroiodomethane	0.25	ND	ND	ND	ND	<0.25 <sup>s</sup>	0.6	<0.25	ND
Dibromoiodomethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Chlorodiiodomethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromodiiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.5	ND	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2	ND	ND	ND	ND	ND		ND	ND
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>									
Monochloroacetic acid <sup>e</sup>	2			ND	ND	ND		ND	
Monobromoacetic acid <sup>e</sup>	1			ND	ND	ND		ND	
Dichloroacetic acid <sup>e</sup>	1			1.9	2.1	4.2		3.9	
Bromochloroacetic acid <sup>e</sup>	1			2.3	1.3	3.9		3.6	
Dibromoacetic acid <sup>e</sup>	1			2.7	2.1	5.4		5.9	
Trichloroacetic acid <sup>e</sup>	1			1.5	1.6	1.6		2.0	
Bromodichloroacetic acid	1			2.0	1.0	1.6		2.3	
Dibromochloroacetic acid	1			ND	ND	1.8		2.0	
Tribromoacetic acid	2			ND	ND	ND		ND	
HAA5 <sup>h</sup>				6.1	5.8	11		12	
HAA9 <sup>i</sup>				10	8.1	19		20	
DXAA <sup>j</sup>				6.9	5.5	14		13	
TXAA <sup>k</sup>				3.5	2.6	5.0		6.3	
<u>Haloacetonitriles</u>									
Chloroacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>e</sup>	0.2	ND	0.2	ND	0.2	ND	NR	ND	0.5
Bromochloroacetonitrile <sup>e</sup>	0.5	ND	ND	<0.5	0.8	1	2	1	2
Dibromoacetonitrile <sup>e</sup>	0.1	ND	ND	0.5	0.6	0.8	0.8	0.3	0.8
Trichloroacetonitrile <sup>e</sup>	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5	ND	ND		ND				
Dibromochloroacetonitrile	0.5	ND	ND		ND				
Tribromoacetonitrile	0.96	ND	ND		ND				
<u>Haloacetaldehydes</u>									
Dichloroacetaldehyde	0.98	ND	ND	1	1	2	2	2	2
Bromochloroacetaldehyde	0.5	ND	0.1	0.9	1	2	2	2	2
Chloral hydrate <sup>e</sup>	0.1	ND	0.2	0.7	0.6	0.5	0.8	1	1
Tribromoacetaldehyde	0.1	ND	ND	0.8	0.5	ND	ND	ND	ND

Table 20 (continued)

03/19/2002	MRL <sup>a</sup>	Plant 1 <sup>n</sup>							
Compound	µg/L	Raw	O <sub>3</sub> Eff	Clear. Eff	Fin. Water	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Haloketones</u>									
Chloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone <sup>e</sup>	0.10	ND	0.4	NR	0.8	NR	NR	1	2
1,3-Dichloropropanone	0.1	ND	ND	0.2	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone <sup>e</sup>	0.1	ND	0.5	<0.5	0.5	0.6	0.6	0.3	0.3
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	ND	ND	0.1	0.2	ND	ND	ND	ND
1,1,1-Tribromopropanone	NA <sup>t</sup>	ND	ND	NR	ND	NR	NR	NR	ND
1,1,3-Tribromopropanone	0.1	ND	ND	0.5	ND	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	0.4	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.1	ND	0.1	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>									
Chloronitromethane	NA	ND	ND	ND	ND	ND		ND	ND
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	ND	ND	ND	ND	0.2	0.2	0.3	0.1
Bromochloronitromethane	0.1	ND	ND	ND	0.1	0.2	ND	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	0.1	ND	ND	ND	ND
Chloropicrin <sup>e</sup>	0.5	ND	NR	ND	ND	<0.5	NR	<0.5	NR
Bromodichloronitromethane	0.5	ND	ND		ND				
Dibromochloronitromethane	2	ND	ND		ND				
Bromopicrin	0.5	ND	ND		ND				
<u>Miscellaneous Compounds</u>									
Methyl ethyl ketone	0.5	ND	ND	ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.2	ND	ND	ND	ND	ND		ND	
1,1,2,2-Tetrabromo-2-chloroethane	0.54	ND	ND	ND	ND	ND	ND	ND	ND
Benzyl chloride	0.5	ND	ND	ND	ND	ND	NR	ND	ND

<sup>e</sup><0.25 or <0.5 or <1 = Detected by GC/MS below its MRL of 0.25 or 0.5 or 1 µg/L;  
quality assurance problem with gas chromatograph method

<sup>t</sup>NA = Not available.

**Table 21. DBP results at plant 2 (3/19/02)**

03/19/2002	MRL	Plant 2°						
Compound	µg/L	Filt. Eff	Treat. Tank	Fin. Water	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Halomethanes</u>								
Chloromethane	0.2		ND	ND	ND		ND	
Bromomethane	0.2		ND	ND	ND		ND	
Bromochloromethane	0.5		ND	ND	ND		ND	
Dibromomethane	0.5		ND	ND	ND		ND	
Chloroform <sup>e</sup>	0.2	NR	15	16	28	NR	25	34
Bromodichloromethane <sup>e</sup>	0.2	NR	17	19	23	NR	25	27
Dibromochloromethane <sup>e</sup>	0.2	NR	6	7	8	NR	8	11
Bromoform <sup>e</sup>	0.2	NR	0.7	0.6	0.7	NR	0.9	0.4
THM4 <sup>f</sup>	0	NR	39	43	60	NR	59	72
Dichloriodomethane	0.25	NR	2	2	2	2	3	2
Bromochloriodomethane	0.25	1	1	1	1	2	1	2
Dibromiodomethane	0.5	0.7	0.5	0.6	<0.5	ND	0.5	ND
Chlorodiodomethane	0.1	NR	<0.5	<0.5	<0.5	NR	<0.5	NR
Bromodiodomethane	0.52	ND	ND	ND	ND	ND	ND	ND
Iodoform	0.5	ND	ND	ND	ND	ND	ND	ND
Carbon tetrachloride	0.2		ND	ND	ND		ND	ND
Tribromochloromethane	0.5	ND	ND	ND	ND	ND	ND	ND
<u>Haloacetic acids</u>								
Monochloroacetic acid <sup>e</sup>	2		ND	2.1	ND		2.2	
Monobromoacetic acid <sup>e</sup>	1		ND	ND	ND		ND	
Dichloroacetic acid <sup>e</sup>	1		18	19	20		22	
Bromochloroacetic acid <sup>e</sup>	1		9.6	6.1	6.2		10	
Dibromoacetic acid <sup>e</sup>	1		3.5	3.4	3.7		4.0	
Trichloroacetic acid <sup>e</sup>	1		14	13	13		16	
Bromodichloroacetic acid	1		9.7	9.2	9.5		11	
Dibromochloroacetic acid	1		2.7	2.4	2.4		3.0	
Tribromoacetic acid	2		ND	ND	ND		ND	
HAA5 <sup>h</sup>	0		36	38	37		44	
HAA9 <sup>i</sup>	0		58	55	55		68	
DXAA <sup>j</sup>	0		31	29	30		36	
TXAA <sup>k</sup>	0		26	25	25		30	
<u>Haloacetonitriles</u>								
Chloroacetonitrile	0.1	ND	0.1	0.1	0.1	0.2	0.2	0.2
Bromoacetonitrile	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloroacetonitrile <sup>e</sup>	0.2	NR	1	2	2	NR	2	3
Bromochloroacetonitrile <sup>e</sup>	0.5	2	1	2	2	1	1	2
Dibromoacetonitrile <sup>e</sup>	0.1	0.8	0.5	0.9	0.5	0.7	0.6	1
Trichloroacetonitrile <sup>e</sup>	0.1	ND	ND	ND	ND	ND	ND	ND
Bromodichloroacetonitrile	0.5			ND	ND			ND
Dibromochloroacetonitrile	0.5			ND	ND			ND
Tribromoacetonitrile	0.96			ND	ND			ND
<u>Haloacetaldehydes</u>								
Dichloroacetaldehyde	0.98	2	2	2	2	2	2	3
Bromochloroacetaldehyde	0.5	0.6	0.7	0.5	ND	ND	ND	ND
Chloral hydrate <sup>e</sup>	0.1	2	4	3	4	4	4	4
Tribromoacetaldehyde	0.1	ND	0.4	0.1	ND	ND	ND	ND

Table 21 (continued)

03/19/2002	MRL	Plant 2°						
Compound	µg/L	Filt. Eff	Treat. Tank	Fin. Water	DS/Ave	DS/Max	SDS/Ave	SDS/Max
<u>Haloketones</u>								
Chloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloropropanone <sup>e</sup>	0.10	NR	2	1	1	NR	1	1
1,3-Dichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1-Dibromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloropropanone <sup>e</sup>	0.1	NR	3	3	2	NR	2	2
1,1,3-Trichloropropanone	0.1	ND	ND	ND	ND	ND	ND	ND
1-Bromo-1,1-dichloropropanone	0.1	0.4	<1	0.9	ND	ND	ND	ND
1,1,1-Tribromopropanone	NA	NR	NR	ND	ND	NR	NR	ND
1,1,3-Tribromopropanone	0.1	0.2	ND	0.1	ND	ND	ND	ND
1,1,3,3-Tetrachloropropanone	0.5	ND	ND	ND	ND	ND	ND	ND
1,1,1,3-Tetrachloropropanone	0.10	ND	ND	ND	ND	ND	ND	ND
1,1,3,3-Tetrabromopropanone	0.1	ND	ND	ND	ND	ND	ND	ND
<u>Halonitromethanes</u>								
Chloronitromethane	NA		ND	ND	ND		ND	ND
Bromonitromethane	0.1	ND	ND	ND	ND	ND	ND	ND
Dichloronitromethane	0.1	0.2	0.3	0.2	0.2	0.3	0.3	0.2
Bromochloronitromethane	0.1	0.2	ND	0.3	ND	0.1	ND	ND
Dibromonitromethane	0.10	ND	ND	ND	ND	ND	ND	ND
Chloropicrin <sup>e</sup>	0.5	NR	<0.5	<0.5	<0.5	NR	0.5	NR
Bromodichloronitromethane	0.5			1	0.8			1
Dibromochloronitromethane	2			ND	ND			ND
Bromopicrin	0.5			ND	ND			ND
<u>Miscellaneous Compounds</u>								
Methyl ethyl ketone	0.5		ND	ND	ND		ND	
Methyl <i>tertiary</i> butyl ether	0.2		ND	ND	ND		ND	
1,1,2,2-Tetrabromo-2-chloroethane	0.54	ND	ND	ND	ND	ND	ND	ND
Benzyl chloride	0.5	NR	ND	ND	ND	NR	ND	NR

**Table 22. Additional Target DBP Results (µg/L) at the EPA Region 9 treatment plants (3/19/02)**

3/19/02	Plant 1 <sup>a</sup>					Plant 2 <sup>b</sup>					
Compound	Raw	OE	FE	PE	DS	FE	TT	PE	DS/a	DS/m	SDS
Monochloroacetaldehyde	0	1.8	2.2	2.4	0	0.2		0		0.3	
Dichloroacetaldehyde	0	0	0	3.5	1.5	2.9		4.2		5.8	
Bromochloroacetaldehyde	0	0	0	1.8	3.0	1.3		1.1		1.2	
3,3-Dichloropropenoic acid	0		0	0	0	0		0		0	
Bromochloromethylacetate	0		0	0	0	0		0		0	
Monochloroacetamide	0		0	0	0	0		0		0	
Monobromoacetamide	0		0	0	0	0		0		0	
2,2-Dichloroacetamide	0		0	0.6	1.1	1.2		3.9		4.5	
Dibromoacetamide	0		0.1	1.6	1.6	0.4		0.8		0.7	
Trichloroacetamide	0		0.1	0.1	0.2	0.3		0.3		0.3	
TOX (µg/L as Cl <sup>-</sup> )	11.3		18.3	145	164	191	234	200	164	243	246
TOBr (µg/L as Br <sup>-</sup> )	4.6		2.0	79.7	50.0	67.0	72.0	76	76	84	86
TOCl (µg/L as Cl <sup>-</sup> )	9.3		20.5	87.2	142	116	202	185	155	195	204
Cyanoformaldehyde	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
5-Keto-1-hexanal	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
6-Hydroxy-2-hexanone	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
Dimethylglyoxal	<0.1	0.4	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
<i>trans</i> -2-Hexenal	<0.1	<0.1	<0.1	<0.1	1.0	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1

<sup>a</sup>Plant 1 DS sampled at maximum detention time

<sup>b</sup>Plant 2 DS sampled at average (a) and maximum (m) detention times

**Table 23. Halogenated furanone results (µg/L) at the EPA Region 9 treatment plants (3/19/02)**

3/19/02	Plant 1		Plant 2		
Compound	FE	PE	FE	PE	DS/max
BMX-1	<0.02	<0.02	<0.02	<0.02	<0.02
BEMX-1	<0.02	0.02	<0.02 (0.01)	0.29	0.18
BMX-2	<0.02	<0.02	<0.02 (0.01)	0.02	<0.02 (0.01)
BEMX-2	<0.02	<0.02	<0.02 (0.01)	0.03	0.04
BMX-3	<0.02	<0.02	<0.02	<0.02	<0.02
BEMX-3	<0.02	<0.02 (0.01)	0.04	0.17	0.06
MX	<0.02	<0.02	<0.02	<0.02	<0.02
EMX	<0.02	<0.02	<0.02	<0.02	<0.02
ZMX	<0.02	<0.02	<0.02	<0.02	<0.02
Ox-MX	<0.02	<0.02	<0.02	<0.02	<0.02
Mucochloric acid (ring)	<0.02	<0.02	<0.02	<0.02	<0.02
Mucochloric acid (open)	<0.02	0.03	0.09	0.10	0.11

Table 12 (10/30/00), Table 18 (7/17/01), and Table 22 (3/19/02) show results for additional target DBPs that were analyzed at the University of North Carolina (UNC). Table 15 (1/23/01) shows results from broadscreen DBP analyses conducted at the U.S. Environmental Protection Agency (USEPA). Table 19 (7/17/01) and Table 23 (3/19/02) show results for halogenated furanones that were analyzed at UNC.

**Summary of tables for halogenated organic and other nonhalogenated organic DBPs**

DBP Analyses (Laboratory)	10/30/00	1/23/01	7/17/01	3/19/02
Halogenated organic DBPs (MWDSC)	Tables 10-11	Tables 13-14	Tables 16-17	Tables 20-21
Additional target DBPs (UNC)	Table 12		Table 18	Table 22
Halogenated furanones (UNC)			Table 19	Table 23
Broadscreen analysis (USEPA)		Table 15		

*Halomethanes.* Figure 7 shows the effect of the different treatment/disinfection scenarios at plant 1 and at plant 2 (for July 2001) on trihalomethane (THM) formation and speciation. The use of ozonation/chloramination significantly reduced THM formation. However, at plant 1, there was a shift to the formation of the more brominated species. Jacangelo and colleagues (1989) also observed that pre-ozonation in bromide-containing waters could result in a shift in speciation upon post-chlorination. In addition, because chlorine was not added until after coagulation at plant 1, the bromide-to-TOC ratio was higher (since coagulation removes TOC, but not bromide), which can also result in a shift in THM speciation (Symons et al., 1993).

**Figure 7**

**Effect of Ozone/Chlorine/Chloramines at Plant 1 and Chlorine/Chloramines at Plant 2 on Trihalomethane Formation and Speciation in Finished Waters (July 17, 2001)**

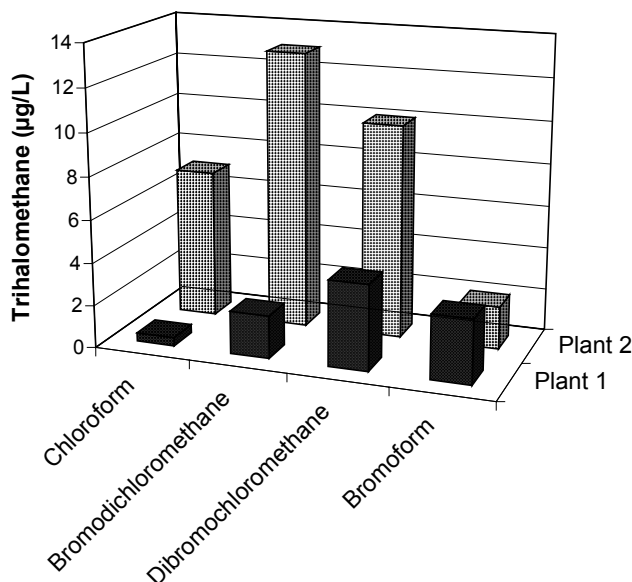
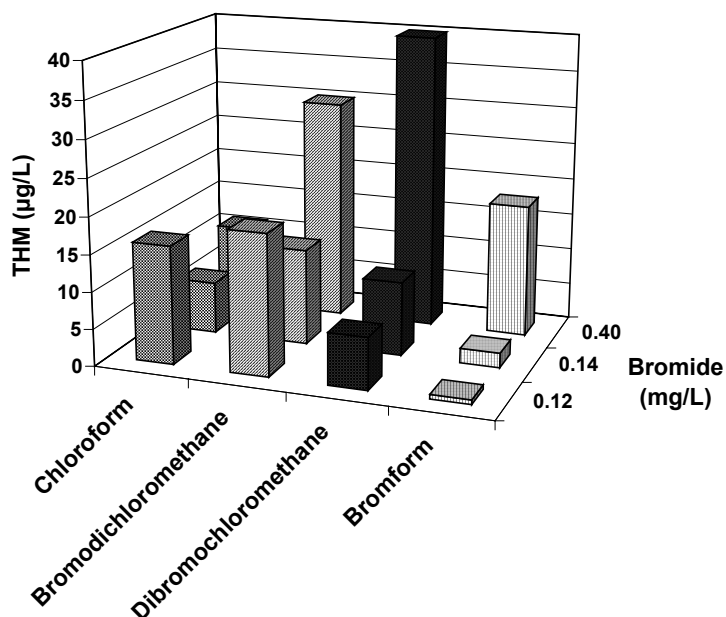


Figure 8 shows the effect of bromide on THM formation and speciation in the finished water at plant 2 for the January 2001, July 2001, and March 2002 samplings. The increase in bromide resulted in more THM formation, as well as a shift in speciation. For example, dibromochloromethane and bromoform formation were significantly higher when the bromide level in the source water increased.

**Figure 8**

**Impact of Bromide on Trihalomethane Speciation  
in Plant 2 Effluent: January 2001 - March 2002**



In addition, low or sub-µg/L levels of iodinated THMs were detected, primarily at plant 2. (At plant 1 and plant 2, saltwater intrusion is the source of bromide and, thus, should also be a source of iodide). For example, in January 2001 (bromide = 0.40 mg/L), 1 µg/L of iodoform was detected in the ozone contactor effluent at plant 1, but was not detected (with a minimum reporting level [MRL] of 0.7 µg/L) in downstream locations. However, 0.3 and 0.2 µg/L of dichloroiodo- and bromochloroiodomethane, respectively, were detected in the chloraminated, distributed water. Broadscreen GC/MS analyses also revealed the presence of dichloroiodomethane and bromochloroiodomethane, as well as dibromoiodomethane in finished water from plant 1 (January 2001) (Table 15). At plant 2, 0.5 and 0.6 µg/L of dichloroiodo- and bromochloroiodomethane, respectively, were detected in the plant after chlorination, and 0.6 µg/L of dibromoiodomethane was detected after chloramination.

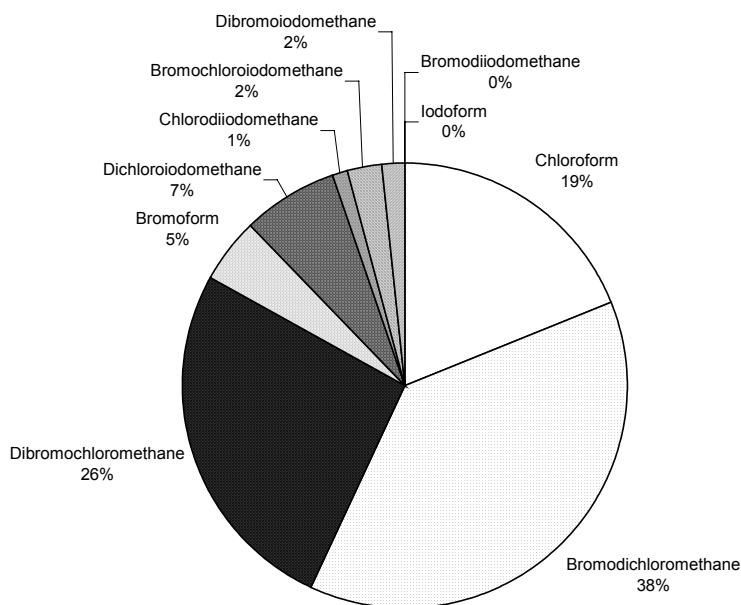
Iodide is oxidized to hypoiodous acid in the presence of ozone, chlorine, or chloramines. Bichsel and von Gunten (2000) found that when ozone ( $O_3$ , 1.0 mg/L) was used on a low-TOC (1.3 mg/L) water ( $O_3$ :TOC = 0.77 mg/mg), no iodinated THMs were detected and  $\geq 90$  % of the iodide was transformed to iodate, whereas chlorine led to the formation of iodate and iodinated THMs. At plant 1 in January 2001, 2.5 mg/L ozone was used on a moderate-TOC (4.5 mg/L)



water ( $O_3:TOC = 0.56$  mg/mg). Although iodate was not measured in this study, the formation of iodoform after ozonation and other iodinated THMs after chloramination suggests that the lower  $O_3:TOC$  ratio did not result in a quantitative conversion of iodide to iodate. However, the use of ozone at plant 1 did result in the formation of less iodinated THMs in the finished water than at plant 2.

Figure 9 shows the THM speciation—including the iodomethanes—at plant 2 in July 2001 (bromide = 0.14 mg/L). Bromodichloromethane was the major species of the four regulated THMs, and dichloriodomethane was the major iodomethane. In both cases, the major THM formed for each group of halomethanes was dichlorinated, with either a bromine or iodine atom as the third halogen.

**Figure 9**



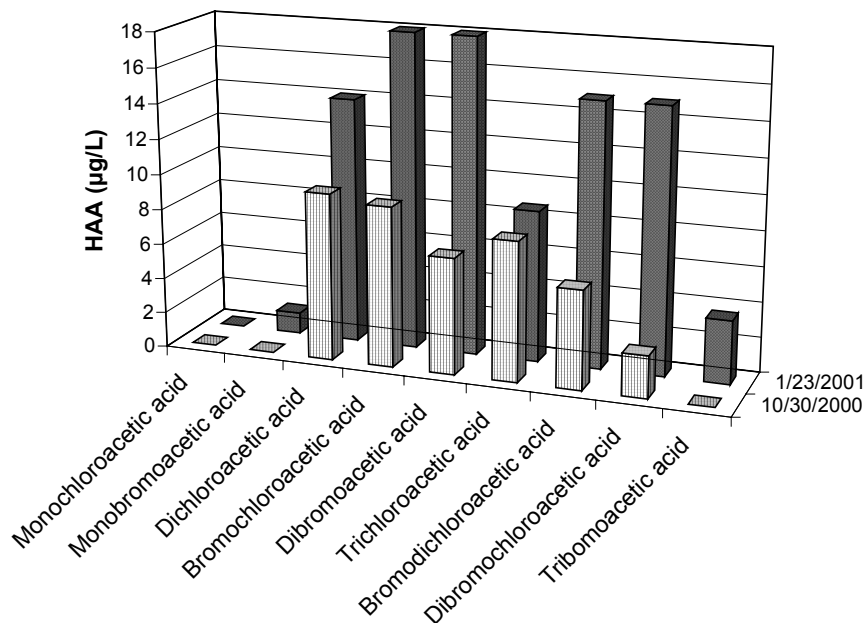
**Trihalomethane Speciation at Plant 2  
SDS (Average Detention Time) Sample (July 17, 2001)**

*Haloacids.* Figure 10 shows the effect of bromide ( $Br^-$ ) on haloacetic acid (HAA) formation and speciation in the finished water at plant 2 for the October 2000 and the January 2001 samplings. For example, tribromoacetic acid was detected when the bromide level in the source water increased, whereas it was not detected when the bromide level was lower. In addition, there was a shift to the formation of the other bromine-containing HAAs.

At plant 2, the sum of the dihalogenated HAAs (DXAAs) was somewhat higher than the sum of the trihalogenated HAAs (TXAAs), whereas at plant 1 the formation of HAAs was almost due only to the DXAAs. In other research, ozonation had been shown to be able to destroy THM and TXAA precursors better than DXAA precursors (Reckhow and Singer, 1984).

**Figure 10**

**Effect of Bromide on HAA Formation and Speciation in Finished Water  
at Plant 2: 10/30/00 Br<sup>-</sup> = 0.16 mg/L; 1/23/01 Br<sup>-</sup> = 0.40 mg/L**



Similarly, chloramination has been shown to be more effective at controlling the formation of THMs and TXAAs than the formation of DXAAs (Krasner et al., 1996).

In addition to the target HAAs, other haloacids were detected in selected drinking water samples by the broadscreen GC/MS methods (Table 15). Plant 1—whose source water had 0.40 mg/L bromide in January 2001—had numerous brominated acids. Fourteen brominated acids (2,2-dibromopropanoic acid, 3,3-dibromopropenoic acid, *cis*-2,3-dibromopropenoic acid, tribromopropenoic acid, 2-bromobutanoic acid, *trans*-4-bromo-2-butenic acid, *cis*-4-bromo-2-butenic acid, 2,3-dibromo-2-butenic acid, bromodichlorobutenoic acid, bromochloro-4-oxopentanoic acid, 3,3-dibromo-4-oxopentanoic acid, 2-bromobutenedioic acid, *trans*-2,3-dibromobutenedioic acid, *cis*-2-bromo-3-methylbutenedioic acid) had not been previously reported in drinking water. Several of these bromo-acids were also seen in finished waters from plant 11 (EPA Region 6), and also in drinking waters from Israel that had been treated with chlorine or chlorine dioxide-chloramine (Richardson et al., submitted).

October 2000 results from UNC indicated the presence of another target halo-acid, 3,3-dichloropropenoic acid, at levels of 0.1 and 0.7 µg/L, respectively, in finished waters from the plant 1 and plant 2 (Table 12).

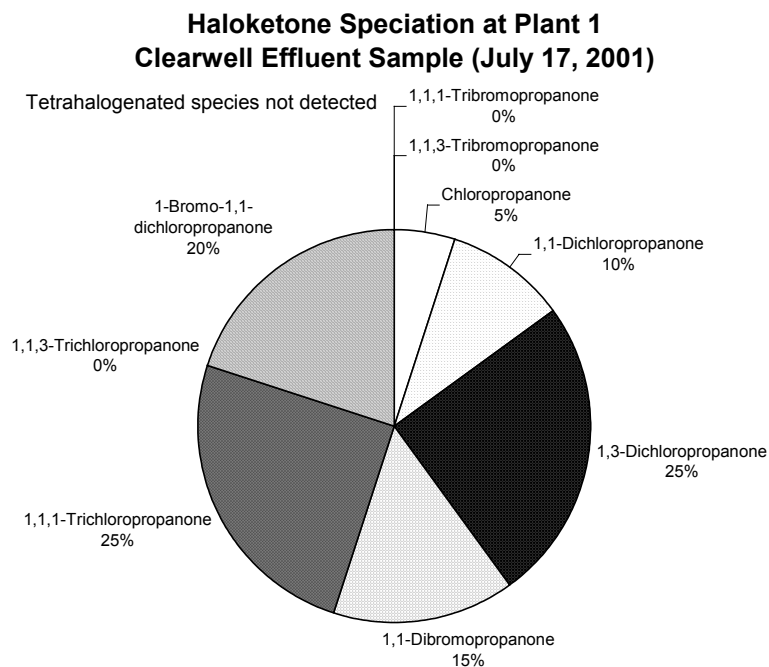
*Haloacetonitriles.* In other DBP research, haloacetonitriles (HANs) were found to be produced at approximately one-tenth the level of the THMs (Krasner et al., 1989). This was also observed in the plant 1 and plant 2 samples. Dichloro-, bromochloro-, and dibromoacetonitrile—

Information Collection Rule (ICR) DBPs—were detected at both treatment plants. Trichloroacetonitrile—another ICR DBP—was not detected; likewise, the brominated analogues of trichloroacetonitrile were not detected. Sub- $\mu\text{g/L}$  levels of chloroacetonitrile were detected at plant 2 in July 2001 and March 2002.

*Haloketones.* In addition to the formation of low levels of haloketone (HK) compounds from the ICR, low levels of 1,1,3,3-tetrabromopropanone were detected in January 2001, primarily at plant 2. The concentration of this HK at plant 2 decreased in the distribution system, and was not detected in the SDS samples. The distribution-system and SDS samples were at a pH of 8.5 to 9.0, thus the disappearance of this HK was probably due to base-catalyzed hydrolysis. (For example, Croué and Reckhow (1989) found that 1,1,1-trichloropropanone—another HK—undergoes base-catalyzed hydrolysis at pH 8.5.) During the October 2000 sampling, this brominated HK was not detected, instead its chlorinated analogue, 1,1,3,3-tetrachloropropanone, was detected. Thus, the higher bromide level in the source water in January 2001 also changed the speciation of this HK.

Low levels of other HKs were also detected in July 2001 (Figure 11). These included a monohalogenated HK (i.e., chloropropanone) and other di- and trihalogenated HKs in which the halogens were not all on the same carbon atom and/or there was bromine substitution.

**Figure 11**



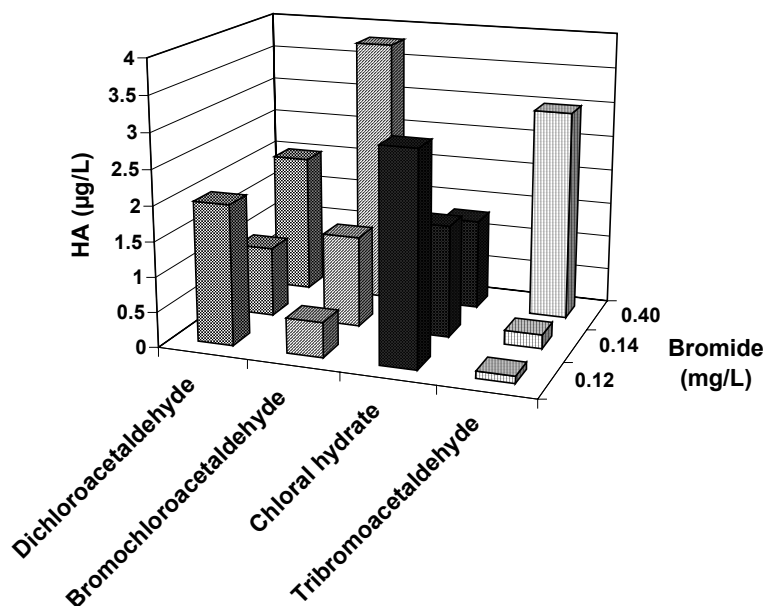
In addition to the target HKs, other HKs were detected by the broadscreen GC/MS methods (Table 15). A number of these HKs were analogous to the di-, tri-, and tetrahalogenated

HKs quantified by MWDSC, except that these were brominated or mixed bromochloro species. For example, in January 2001, when the raw-water bromide was at 0.40 mg/L, MWDSC detected 1,1-dichloro-, 1,1,1-trichloro-, and 1,1,3,3-tetrabromopropanone after chloramination and ozonation at plant 1. Broadscreen GC/MS analysis of this same water also detected two brominated analogues of 1,1-dichloropropanone, two brominated analogues of 1,1,1-trichloropropanone, and a bromochloro analogue of 1,1,3,3-tetrabromopropanone. Most were observed in the finished water that had been treated with secondary chlorine and chloramine, but some were also seen in waters from the ozone contactor effluent. The chlorinated species were likely formed by the twice-a-week treatment of the flocculation and sedimentation basins with chlorine (which was applied at the ozone contactor effluent) to control algal growth, and not by the treatment with ozone. Alternatively, the brominated species may have been formed by ozone, as ozone can oxidize bromide to hypobromous acid, which can react with TOC to form brominated DBPs.

*Haloaldehydes.* Figure 12 shows the impact of bromide on haloacetaldehyde speciation in the plant effluent of plant 2. When the bromide level was the highest (0.40 mg/L), there was a significant formation of bromochloro- and tribromoacetaldehyde. When the bromide

**Figure 12**

**Impact of Bromide on Haloacetaldehyde Speciation  
in Plant 2 Effluent: January 2001 - March 2002**



concentration was lower (0.12-0.14 mg/L), both of these brominated species were formed at lower levels and the formation of the chlorinated species (dichloroacetaldehyde and chloral hydrate) were the major haloacetaldehydes produced.

Likewise, when the bromide level was the highest, there was a significant formation of the bromine-containing THMs (bromodichloromethane, dibromochloromethane, and bromoform) (Figure 8). When the bromide concentration was lower, bromoform was formed at lower levels, and the formation of the chlorine-containing species (chloroform and bromodichloromethane) were typically the major THMs produced.

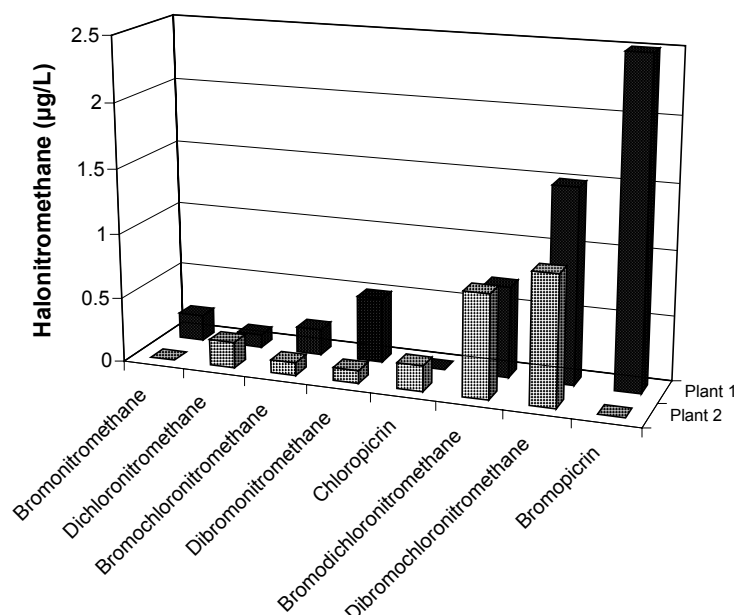
In January 2001, tribromoacetaldehyde decreased in concentration in both sets of distribution-system and SDS samples, whereas the dihalogenated acetaldehydes increased in concentration in the distribution-system and SDS samples for plant 1. Moreover, the concentration of bromochloroacetaldehyde was higher in the distribution-system and SDS samples at plant 1 than at MSWTP. The results for tribromoacetaldehyde are consistent with the research of Xie and Reckhow (1996), who found that tribromoacetaldehyde degraded quickly at pH 9.0. In other research, acetaldehyde (an ozone by-product) was found to react with chlorine to form chloroacetaldehyde, which in the presence of free chlorine rapidly reacted to form chloral hydrate (McKnight and Reckhow, 1992). At plant 1, chlorine (in the presence of ammonia and bromide) may have reacted with acetaldehyde formed by the ozonation process to produce dichloro- and bromochloroacetaldehyde.

In addition to the target haloacetaldehydes, another brominated aldehyde (2-bromo-2-methylpropanal) was detected by the broadscreen GC/MS methods (Table 15).

*Halonitromethanes.* In addition to low levels of chloropicrin (trichloronitromethane) (an ICR DBP), low or sub- $\mu\text{g/L}$  levels of other halonitromethanes (HNMs) were detected in the selected samples (Figure 13). Although ozone/chlorine/chloramines at plant 1 produced less THMs than chlorine/chloramines produced at plant 2 (Figure 7), a higher concentration of the trihalogenated HNMs was detected at plant 1 in July 2001 (Figure 13) (this was not the situation in March 2002). In other research, pre-ozonation was found to increase chloropicrin formation upon post-chlorination (Hoigné and Bader, 1988). In addition, the speciation of the trihalogenated HNMs was similar to the speciation of the THMs. At plant 2, the bromochloro species predominated, whereas at plant 1 there was more of a shift to the formation of the more fully brominated species.

Figure 13

Effect of Ozone/Chlorine/Chloramines at Plant 1 and Chlorine/Chloramines at Plant 2 on Halonitromethane Formation and Speciation in Finished Waters (July 17, 2001)



*Halogenated furanones.* Tables 19 and 23 show results for halogenated furanones in the July 2001 and March 2002 samplings for the EPA Region 9 treatment plants. Data are included for 3-chloro-4-(dichloromethyl)-5-hydroxy-2[5H]-furanone, otherwise known as MX; (E)-2-chloro-3-(dichloromethyl)-4-oxobutenoic acid, otherwise known as EMX; (Z)-2-chloro-3-(dichloromethyl)-4-oxobutenoic acid (ZMX); the oxidized form of MX (Ox-MX); brominated forms of MX and EMX (BMXs and BEMXs); and mucochloric acid (MCA), which can be found as a closed *ring* or in an *open* form. Results are displayed graphically in Figure 14.

In July 2001, 3-chloro-4-(dichloromethyl)-5-hydroxy-2[5H]-furanone, otherwise known as MX, was detected at plant 2 but not at plant 1 (with an MRL of 0.04 µg/L) (Table 19; Figure 14). This is probably because ozone in the plant 1 treatment scheme removes MX precursors from the raw TOC, while chlorine in the plant 2 treatment scheme reacts with the raw TOC to form MX. Likewise, plant 1 produced less THMs than plant 2 (Figure 7). The filter effluent sample from plant 2 contained a higher concentration of MX (120 ng/L) than reported in a survey of Australian waters (<90 ng/L) (Simpson and Hayes, 1998). However, water quality and treatment/disinfection schemes may be different in Australia than in the United States. In particular, regulatory requirements in Australia are significantly different than in the United States. MX appears to degrade between the filter effluent and the distribution system (DS)/average sample of plant 2. However, water in the distribution system may represent a blend of water from more than one treatment plant. In addition, water in the distribution system may represent water produced at plant 2 on a previous day, as the survey was not set up to follow a “plug” of water *per se*. The second sampling of plant 1 and plant 2 (March 2002) for

halogenated furanones showed similar trends, such as removal of MX-analogue precursors by ozonation in plant 1, when compared to plant 2 (Table 23, Figure 15). Overall, plant 2 exhibited higher concentrations of mucochloric acid (MCA *open*) and brominated MX-analogues than plant 1. Within the distribution system of plant 2, BEMX-1 appeared to decrease (from 290 ng/L in the plant effluent to 180 ng/L in the DS/maximum sample) and BEMX-3 appeared to decrease (from 170 ng/L in the plant effluent to 60 ng/L in the DS/maximum sample). Because TOC and bromide levels in the source water of this treatment plant can vary frequently (Krasner et al., 1994)—as well as the pH of the water (which can significantly vary on a diurnal basis)—differences between the plant effluent and the distribution system (particularly at a maximum detention time) may be due (in part) to a comparison of different “packets” of water treated at different points in time. Alternatively, analysis of SDS samples for halogenated furanones would have allowed for a more direct assessment of the impact of distribution system detention time, etc., on the formation and stability of these DBPs.

**Figure 14**

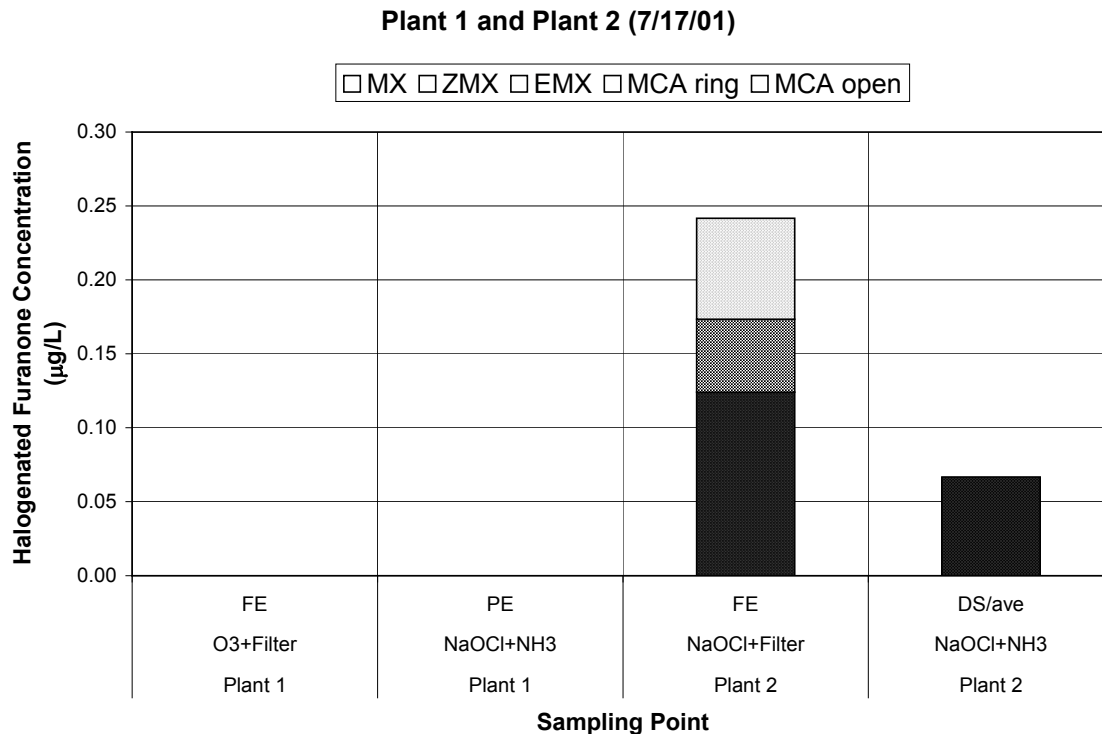
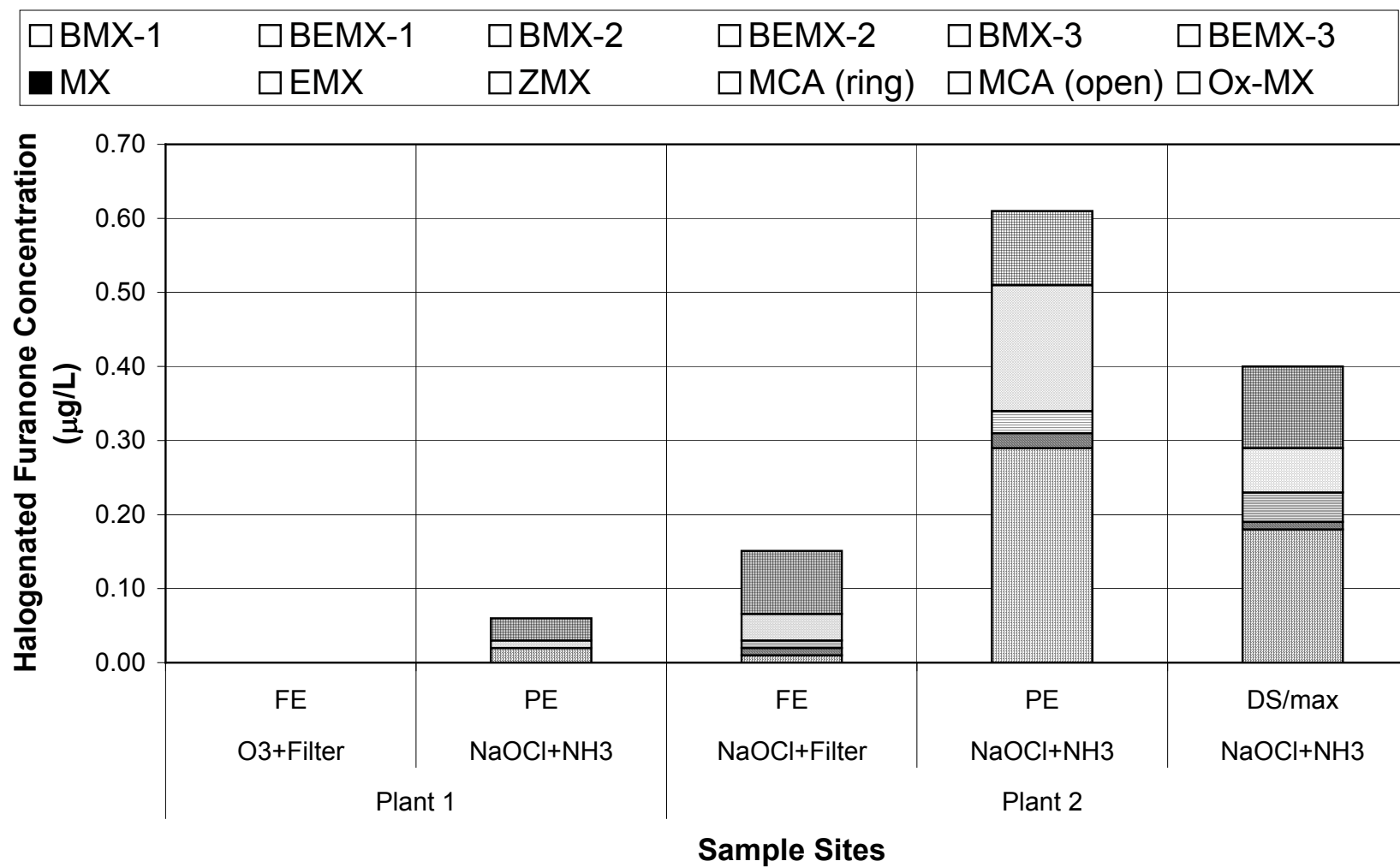


Figure 15

**Plant 1 and Plant 2 (3/19/02)**





*VOCs.* Although methyl *tertiary* butyl ether (MtBE) is not a DBP, it is a VOC that was included in this study. In January 2001, 0.3 µg/L of MtBE was detected in the raw water sample. The same level of MtBE was detected in the treated waters at plant 2, whereas a somewhat lower level (i.e., 0.2 µg/L) was detected at plant 1. In other research, ozone has been shown to destroy (at least in part) MtBE (Liang et al., 1999). If the decrease in MtBE at plant 1 was real, this could have been due to ozonation.

Methyl ethyl ketone (MEK) is also a VOC. In addition, it was detected after ozonation at plant 1 in July 2001. Non-halogenated ketones can be formed by ozone (Glaze et al., 1989). MEK was not detected downstream of the ozone contactor effluent (with an MRL of 0.5 µg/L), perhaps due to biodegradation through the downstream treatment processes.

*Other Halogenated DBPs.* A few additional, miscellaneous halogenated DBPs were also detected. UNC methods detected dichloroacetamide at 0.2 and 0.8 µg/L in finished water, respectively, from plant 1 and plant 2 in October 2000 (Table 12). Bromochloromethylacetate was also detected in finished waters from plant 1 at 0.1 µg/L (Table 12). In addition, broadscreen GC/MS analyses revealed the presence of chlorobenzene and tribromophenol (Table 15) in finished waters from plant 1 (January 2001). None of these compounds were observed in the corresponding raw, untreated water.

*Non-Halogenated DBPs.* The plant 1 ozonated drinking water offered one of the few times that cyanoformaldehyde was detected in the Nationwide DBP Occurrence Study. Cyanoformaldehyde had been first identified in a DBP study published in 1999 on ozonated drinking waters from a pilot plant (Richardson et al, 1999). Cyanoformaldehyde was found in the finished water at plant 1 in October 2000 at 0.2 µg/L, and its concentration remained steady at 0.2 µg/L in the distribution system (Table 12). Cyanoformaldehyde was also found in finished waters from plant 2 (which used chlorine disinfection) at 0.3 µg/L (October 2000). Dimethylglyoxal was also seen in ozone contactor effluent samples from plant 1 in both October 2000 and July 2001, but was below detection in the finished water (plant effluent). In the July 2001 sampling, it appeared to be removed by biological filtration, but in the October 2000 sampling, its levels decreased between the filter effluent sampling and the plant effluent, indicating a possible reaction with the secondary chlorine-chloramine that was added following filtration. Broadscreen GC/MS analysis also revealed the presence of glyoxal and several non-halogenated carboxylic acids in samples from plant 1 in January 2001 (Table 15). Several of these carboxylic acids were also seen in the raw, untreated water, but those listed as DBPs in Table 15 represent those whose levels increased substantially (2-3X) in the treated waters vs. the raw, untreated waters.

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